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[THIRD SERIES.]

ART. XXIII.—*On the Feasibility of Establishing a Light-wave as the Ultimate Standard of Length;* by ALBERT A. MICHELSON and EDW. W. MORLEY.

IN the problem of making a light wave a practical standard of length, it is desirable to use as an intermediate standard a metal bar bearing two plane surfaces at the greatest distance apart at which interference (between two pencils having this difference of path) is accurately measurable. Some preliminary experiments have shown that in the case of the green mercury wave the distance may be a fourth of a meter. To keep well within limits, however, it is safe to say that an intermediate standard one-eighth of a meter long is entirely practicable. Such a distance will contain about a quarter of a million waves. The fractions of a wave present no especial difficulty; but to find the whole number when it is so large is not so simple a matter.

The following plan has been adopted and it is believed that by its means the chances of error are reduced to a minimum.

A series of intermediate measures were constructed alike in all respects save that the distances between the two planes were made very nearly 2^{-11}, 2^{-10}, 2^{-9}, 2^{-8}, 2^{-7} of a meter.

A description of one of these will answer for all. It consists of a brass bar provided with two sets of brass studs against which are pressed by spiral springs two silvered glass pieces two cm. square and about 0·6 cm. thick. The reflection takes place from the front surface, and the distance between these surfaces was adjusted as follows:—

The plane-parallel glasses are pressed by springs against three brass studs which are adjusted by filing away the studs to within a few waves of the desired length, and till the angle between the planes was less than half a second. The former operation was effected by the instrument described at the meeting of the National Academy in New Haven, which for want of a better term may be called the "interferential comparer." And the latter by the "refractometer" also previously described.

The relation between these intermediate bars which, commencing with the shortest (about half a millimeter), shall be designated *A B C D E F G H I*, was then determined with a mean error of a fifth of a wave, as described below, by the "comparer," and the last one compared directly with a standard meter. Thus the absolute length of *A* was found to be 0·4891 mm. ± 0·0001 mm. This was divided by the wave-length of sodium light taken from Rowland's tables and $2A$ was thus to contain 1659·1 ± ·2 of the longer sodium waves ($\lambda = 5896{\cdot}08$). *A* was then placed in the refractometer and the correct fraction found to be ·01 instead of ·10; so $2A = 1659{\cdot}01\lambda_D$. With this corrected value of the length of *A*, *B* was found to contain 3314·22 waves, and, when corrected by the refractometer, 3314·27 waves.

Similarly *C* was found to contain 6617·84 waves, and when corrected, 6617·90. *D* contained 13237·00, corrected, 13236·99; and *E* contained 26472·08, corrected, 26472·18.

The same process was repeated for other kinds of light to diminish the chances of error. Besides yellow sodium and red lithium, the three bright radiations of mercury in a vacuum tube were used; namely, a moderately bright double line in the yellow, a very brilliant line in the green, and a fainter one in the violet.

The approximate wave-lengths of these were found by direct comparison with the solar spectrum and Rowland's maps as follow:

	Na_1	5896·08
	Na_2	5890·1
	Li	6707·8
Hg	Y_1	5769·8
Hg	Y_2	5790·6
Hg	G	5460·6
Hg	V	4358·5

In the case of sodium it is somewhat difficult to obtain good results because the two series of interferences overlap, and especially so because they are of unequally varying intensities. When the flame is bright the intensities are nearly equal—but then the light is not sufficiently pure. When the light is faint Na_2 is nearly twice as bright as Na_1. Hence to find the fraction

corresponding to Na_2 a correction of one-third the phase-difference between the two was added. The sodium flame gave good interference rings with E the longest standard used; but when longer standards are used it will be better to use the vacuum tube.

The lithium flame gives very indistinct interference circles but is valuable as a check on account of its great wave-length.

The yellow mercury light has the inconvenience of being double; but the two radiations are of nearly equal intensities. When, however, the phase-difference amounts to nearly half a wave it may be necessary to add or subtract half a wave from the observed result.

The brilliant *green* line gives beautifully clear circles even with a difference of path of half a million waves, so that in all probability *this will be the wave to be used as the ultimate standard of length.* So far as mere errors of setting are concerned, it is easy to obtain results consistent to a fiftieth of a wave, and with care to a hundredth.

The violet is also perfectly clear but the light much fainter. Its short wave-length makes it very valuable as a check.

As has been elsewhere shown the refractometer gives precisely the same interference phenomena as two surfaces enclosing a plate of air. One of these surfaces corresponds to one of the mirrors on the standard; the other to the *image* of another mirror. This image will be called the "reference plane."

The standard, A, let us say, which has already been carefully adjusted for length and parallelism is placed in the refractometer and the distance of the reference plane adjusted till the interference rings are equally distinct on the upper (rear) and the lower (front) surfaces of A. Then the reference plane is made to bisect the (extremely small) angle between the upper and lower surfaces. This is accomplished by adjusting till there is no alteration in the diameter of the rings on either surface when the eye is moved vertically or laterally (if the angle is zero); or till the alteration is equal and opposite on the two surfaces.

This adjustment is effected by means of the sodium flame, without the observing telescope. Temperature and barometric pressure are then taken. The reference plane is then moved by a fine adjustment till the central spot is black (phase = zero) on the upper (mirror) and the diameter of the first ring measured by the Troughton micrometer; and the telescope is then lowered and the width of the first ring on the lower surface measured. Then the phase difference at the lower surface is adjusted to zero, and diameter of first ring measured; and then the telescope is raised and width of first ring on upper mirror is measured.

The square of the ratio of two successive measurements on the mirror farthest from the reference plane will be the required result, and should agree, except in sign, with the corresponding result for the nearer mirror.

The following is a specimen observation:

March 12. A Sodium, T = 17°·0, B = 74·55^{cm}

Upper Mirror.		Lower Mirror.	
557	zero	542	----
----	274	zero	600
572	zero	554	----
----	260	zero	588
Means 564	267	548	594

$$\left(\frac{267}{564}\right)^2 = 0{\cdot}22 \qquad -\left(\frac{548}{594}\right)^2 = -0{\cdot}86 = +0{\cdot}14$$

$$0{\cdot}14$$

Final mean = 0·18

− 0·19 = corrections for therm., barom. and phase.

Final result = ·99

The mercury light was obtained by passing sparks from an induction coil through an "end on" vacuum tube enclosed in a galvanized iron box heated by a Bunsen burner. Before passing to the refractometer it was analyzed by a single carbon-disulphide prism. By moving the source, yellow, green, or violet light could be examined at pleasure.

The comparison of intermediate bars is effected as follows:

The bar, B, let us say, is held on a fixed support attached to the bed of the comparer, and A is held on a movable carriage so that the two are side by side with their lower mirrors in the same plane. The reference plane is adjusted to make a small horizontal angle with the surfaces of B (the vertical angle being adjusted to zero) and then the surfaces of A are adjusted to parallelism with B. The carriage holding the combination equivalent to the "reference plane" is then released from all contact with adjusting screws. The fringes in white light under these conditions are vertical lines on the lower surfaces. The distance (in fractions of a fringe) between the central black fringes and marks on each mirror is noted.

The reference plane is now moved back till it coincides with the upper mirror on A when the fringes in white light appear on this surface and the position of the central black fringe is again noted.

Next A is moved back till the *lower* mirror coincides once more with the "reference plane" and finally the latter is moved

back till it coincides with the *upper* mirrors of both *A* and *B if* B *is just twice* A. If not, the fringes and fractions in the difference are noted.

In the actual experiment the fringes always were adjusted to move to the right (in the observing telescope) when the reference plane was moving from the observer.

The following table gives the final results from the observations on *E* in wave-lengths. After the first series was completed all the standards were altered in length and adjustment. Series III was taken by another observer.

Ser. I	5896·08	6707·98	5460·85	5790·70	4358·42
Ser. II	5896·08	6708·00	5460·85	5790·67	4358·42
Ser. III	5896·09	6708·00	5460·85	5790·68	4358·41
Mean	5896·083	6707·993	5460·850	5790·683	4358·417

The arguments for the accuracy of these results are as follows:

1st. In every step of every series the mean difference between observation and calculation is less than it is when the whole number selected is either greater or less.

2d. In every step of every series the maximum difference between the greatest and least values of the errors is less than it is when the whole number selected is either greater or less.

3d. In every step of every series the difference between the errors of the longest and shortest waves, namely, lithium and violet mercury, is less than it is when the whole number is either greater or less.

4th. In every step of every series the number selected as agreeing most nearly with the results of observation differs less than six tenths of a wave, and usually less than three tenths of a wave from the number found by the comparer.

5th. In every step the results of the three independent series agree within 0·15 of a wave.

It may be considered reasonably certain therefore that the number of waves in the distance between the two planes of the standard *E* is known to within about one part in a million. It is also reasonably certain that the distance may be increased at least eight fold and hence the error reduced to less than one part in eight millions.

These results have been attained with apparatus having many imperfections and inconveniences. With better appliances and with the benefit of the experience gained it is hoped the last trace of uncertainty may be removed and the whole operation of establishing a material standard a meter long whose length in light waves is known to within one part in one million, and perhaps one in ten millions may be accomplished with ease and certainty.

POSTSCRIPT.

As has been previously stated, the only serious source of error to be feared in this method is a mistake in the whole number of waves in one or more of the "intermediate standards."

Notwithstanding the cumulative evidence just cited, it must be admitted that such a mistake may have occurred—and the numbers given in the table would require further and independent confirmation before being accepted as final.

Some months after the preceding paper was read a letter was received from Professor Rowland giving numbers for the relative wave-lengths of sodium and mercury lines by the grating method, as follows:

The upper line repeats the means of the preceding table corrected to agree with the latest of Rowland's tables by adding $\frac{1}{80000}$; the lower are Rowland's figures.

	Na_1	Hg	Hg_1	Hg_2
M. & M.	5896·157	5460·918	5790·755	4358·470
R.	5896·156	5460·94	5790·86*	4358·49

*Marked "poor reading."

In view of this final and almost complete confirmation these results may be taken not merely to prove the feasibility of the method, but as an accurate and reliable measurement of the relative wave-lengths of these radiations. As the whole number of waves used in this work was but a tenth of the number to be used in the final work—and as the relative error will be diminished in this proportion, nearly, it would seem that the claim made for the possible degree of accuracy attainable by this method of measurement has already been justified.

ART. XXIV.—*The Carboniferous Echinodermata of the Mississippi Basin;* by CHARLES R. KEYES.

DURING the deposition of the Lower Carboniferous rocks, life throughout the interior of North America was remarkable for the immense development and expansion of piscine and echinodermatous types; and among the latter especially, for the culmination of crinoidal and blastoidal forms. Not only was the development of the Crinoidea phenomenal in the number of species, but the extensive numerical representation of individuals was most astonishing. So prolific was crinoidal life at this period that the disjointed skeletal remains form great beds of what may be appropriately denominated a crinoidal breccia; which, however, is not always compact, but frequently full of

interstices, with scarcely any finer and cementing materials; while throughout are disseminated broken and shattered calyces, fragments of arms, and portions of stems. Other parts of the formation exhibit thick beds of compact massive limestone alternating with layers of less durable composition. In some of the thin, sandy or clayey partings, lying half imbedded in the surface of hard limestone are often myriads of stemmed feather-stars, perfect as the day when they were entombed—forms of wondrous beauty and rare delicacy, gracefully and intricately intertwined like some rich flowing arabesque; and depicting accurately and distinctly the conditions of their surroundings when they waved to and fro in the quiet depths of the great Carboniferous sea.

Composed of regular plates, definitely arranged and frequently highly ornamented, delicate arms and characteristic stems, these organisms were admirably adapted for recording all marked changes in the physical conditions of their habitat. The testimony of the crinoids, corroborating the stratigraphic evidence, points to a slow and very gradual alteration of the sea-bottom. The long period of quietude over the broad Mississippi basin imposed especially favorable conditions of environment for a wide geographic and geologic dispersion of the various species. And the great uniformity of these conditions over extended areas is amply attested by the occurrence of identical species in localities as widely separated geographically as eastern Iowa and the Lake Valley region of New Mexico; or as central Illinois and the southern prolongation of the Appalachians in Alabama. But notwithstanding the extensive distribution of many species, the large majority of Paleozoic echinoderms was very limited in space and especially in time. Those species therefore which experienced a wide dispersion form valuable and reliable criteria for synchronizing horizons far removed from one another. The equivalency, however, of strata of distant localities can at best be only approximately determined from paleontological data alone. As has been suggested by Williams,* the biologic sequence in any limited region is not indicative of the genetic succession of the inhabitants, but merely the sequence of occupants within that particular area. The gradual oscillation and change of habitat to which the Carboniferous echinoderms of the Mississippi basin were subjected would tend to make their migrations extend through longer periods of time and their specific existence more protracted than the stratigraphy of any one place would indicate. And thus certain species would become extinct in one region and be completely replaced by very different forms; while in distant localities the migratory species would continue to flourish in all their wonted vigor.

* Proc. Am. Association Ad. Sci., vol. xxxiv, p. 232, 1885.

Echinodermatous life during the Lower Carboniferous was preëminently crinoidal and blastoidal: the former greatly predominating in the earlier part, and the latter conspicuously present in the later portion of the period. So marked is the contrast between the faunal features of the middle and upper portions of the Lower Carboniferous that Wachsmuth and Springer* have suggested that the Burlington and Keokuk deposits could very appropriately be called the "crinoidal limestone"; while the St. Louis and Chester are manifestly a "blastoidal" division.

In the subjoined synoptical† table are arranged the principal Carboniferous genera of the Pelmatozoa, and their distribution through Paleozoic time. Inasmuch as the synonymy of the species has been worked out more carefully and accurately than in any other group of fossils, the table is especially reliable for the consideration of problems of distribution during geologic times. The figures in the various columns refer to the number of species of each genus at present known from the respective beds. In cases where species existed through more than one epoch they are referred to the division in which they occur most abundantly. The faunas of the Upper and Lower Burlington limestones are so well marked that for convenience the species of each are considered separately. The abbreviations are: L. S.=Lower Silurian, U. S.=Upper Silurian, D.=Devonian, W.=Waverly or Kinderhook, L. B.=Lower Burlington, U. B.=Upper Burlington, K.=Keokuk, L.=St. Louis, C.=Chester, M.=Coal Measures.

The genera enumerated in the accompanying synoptical table, while characteristically Carboniferous, are very unequally distributed in time. In nearly every instance each genus exhibits: (1) a gradual expansion after its first appearance, shown by the differentiation of species occurring in each epoch; (2) a culmination, marked not only by a larger number of species and a great numerical increase of individuals, but also by a remarkable development and specialization of various structural characters, and by a more or less wide distribution in space; and (3) a decrease in the number of species, and a very apparent decline in physical energy, generally terminating in a more or less abrupt extinction of the group. The culmination of crinoidal‡ life generally was in the middle

* Proc. Acad. Nat. Sci. Phila., 1878, p. 229.

† The table is based chiefly upon the extensive collections of Messrs. Wachsmuth and Springer. The echinoderms other than crinoids and blastoids have purposely been omitted for the reason that at the present time perfect confusion exists throughout. However, as accurately as can be determined from all available sources the omission affects in no way the general conclusions arrived at, in regard to the Pelmatozoa alone.

‡ It must be borne in mind that the terms Crinoidea, Crinoids and their derivatives are limited to ordinal application, equally with Blastoidea and Cystidea, which are included under Pelmatozoa. There is a general practice prevalent of applying the name Crinoidea to all stemmed echinoderms, thus making the term co-extensive with Pelmatozoa, while in reality it is only a subdivision of the latter.

Synoptical Table of Carboniferous Echinodermata.

Genera of Pelmatozoa.	Pre-Carboniferous.			Lower Carboniferous.						U. C.
	L. S.	U. S.	D.	W.	L. B.	U. B.	K.	L.	C.	M.
Crinoidea.										
CAMERATA.										
Gilbertsocrinus			2		3	2	1			
Rhodocrinus			3	3	6	2	2	1		
Agaricocrinus				2	4	7	6			
Alloprosallocrinus							1			
Periechocrinus		3			2	1				
Megistocrinus			9	2	2	1				
Actinocrinus				4	21	6	5			
Teleiocrinus						9				
Steganocrinus				1	3	1				
Amphoracrinus				1	2					
Physetocrinus					2	3				
Strotocrinus						2				
Batocrinus				1	8	12	15	5		
Erstmocrinus					7	8	5			
Dorycrinus			1	1	5	4	3			
Platycrinus			2	6	23	13	5	7	1	
Eucladocrinus						2				
Dichocrinus				2	7	6	4	2		
Talarocrinus								1	4	
Pterotocrinus									10	
ARTICULATA.										
Ichthyocrinus		5			1	1				
Taxocrinus	2		5	4	2	1	4	2		
Forbesiocrinus						1	2		2	
Onychocrinus				1		2	3	1	2	
Nipterocrinus					1	1				
INADUNATA.										
Larviformia.										
Allagecrinus									1	
Symbathocrinus			1	1	2	2	1			
Belemnocrinus					2	2				
Atelestocrinus					1	1				
Vasocrinus			2		1		1			
Baryocrinus					2	3	15	2		
Cyathocrinus	3	4		1	5	5	9			
Fistulata.										
Poteriocrinus			2		3	1				
Scaphiocrinus			1	3	5	9	14	7	11	
Scytalocrinus						1	4	3	5	
Decadocrinus			5	4	2	2	2	1	2	
Woodocrinus			1	1	1	2	3	1		
Zeacrinus					1	5	1		6	
Hydreionocrinus									3	4
Cromyocrinus									2	
Eupachycrinus									4	2
Graphiocrinus					5	2	1			
Agassizocrinus									9	1
Calceocrinus	2	3	3		1	1	2			
Catillocrinus						1	2			
Blastoidea.										
Schizoblastus				1	3	2	1			
Cryptoblastus					1	1				
Granatocrinus				1		2				
Heteroblastus								1		
Pentremites						2		4	28	
Mesoblastus								1		
Codaster		2	9			1	1			
Metablastus						1	2	2		
Orophocrinus					3					
Tricœocrinus							1	4		
Phanoschisma					1					
Troostocrinus								1		

of the Lower Carboniferous. At the close of the Keokuk epoch one-half of the Carboniferous genera had become extinct. The great group Camerata had passed away, with the exception of the Hexacrinidæ and a few depauperate forms of several other genera whose existence was quickly brought to a close. A large proportion of the genera in the extensive section Inadunata had disappeared; of those groups which survived to the close of the period, a diminutive species *Allagecrinus* (a single specimen only being at present known) was the sole representative of the branch Larviformia; while of the great group Fistulata only the typical genus (including four subgenera) of the Poteriocrinidæ extended through the entire Lower Carboniferous. And the widely distributed *Calceocrinus* which began back in the Lower Silurian became extinct just before the beginning of the St. Louis.

Wachsmuth and Springer* have shown that in the expansion and geological development of the various groups of crinoids the modification of specific characters was very gradual and corresponded in a striking manner with the changes by growth in the individual. Another suggestive fact is that usually the more generalized types of the various groups are the more persistent, often having a considerable range both in time and space. The expansion of the several families is also frequently indicated by the relatively rapid development, in some suprageneric groups, of certain structural features which soon become curiously differentiated. Perhaps nowhere in any zoological group is its culmination better or more clearly defined, in accordance with the suggestions already made, than in the Crinoidea. The remarkable multiplicity of specific and generic types, appearing in rapid succession during the middle Lower Carboniferous; the extreme and phenomenal specialization of particular anatomical structures; the great increase in size; the ponderous character of the test; and the marked structural changes in many minor particulars are of peculiar biological significance. Toward the close of the Keokuk nearly all the specialized forms became extinct; and with a very few exceptions only the more generalized types continued through the Lower Carboniferous—only such forms as were ordinally related to living crinoids.

If the crinoids formed a prominent faunal feature of the earlier part of the Lower Carboniferous, the blastoids were equally conspicuous during the latter portion of the period. In the Burlington and Keokuk the Blastoidea, although represented by more genera than in the St. Louis and Chester, were for the most part rare individually; and their presence was rendered still less noticeable by the great preponderance of

* Proc. Acad. Nat. Sci. Philad., 1878.

associated crinoids. During the St. Louis and Chester the blastoids were greatly in the ascendancy. This was due partly to an immense expansion in the order itself, and partly to a further marked numerical decrease of the crinoids, which had already become astonishingly reduced. Though the blastoids, in number of genera, were not as abundant in the latter, as in the former, part of the period, individually they were exceedingly numerous.

Recent investigations show that the divisions of the Lower Carboniferous as generally recognized in the continental interior are not as clearly marked by abrupt changes in faunal and lithological features as current opinion considers, and as has been very strongly urged, particularly by some of the earlier geologists. It is now conceded that some of the present divisions of the Lower Carboniferous as presented throughout the region in question, could be very appropriately united. That several of these divisions are very closely related cannot be questioned. There is conclusive proof,* at least so far as the most characteristic faunal group is concerned, that the Burlington and Keokuk are more closely related than the two limestones (upper and lower) of the former division. Investigations instituted among the Gasteropoda and Brachiopoda afford like evidence as to the near relationship of the two formations as usually designated.

From a comparison of the Crinoidea occurring in the Upper and Lower Burlington, and Keokuk limestones it is quite apparent, as first observed by White† and afterwards more fully discussed by Wachsmuth and Springer‡ that the forms of the three horizons present some marked differences. Those species from the lower Burlington are of small size, delicately constructed and ornamented; in the upper division of the Burlington the peculiar delicacy pervading the lower bed forms is absent, or has assumed a ruder character; while in the Keokuk the crinoids are characterized by large size, rough massive construction, bold rugged ornamentation, and a conspicuous exaggeration in many structural details. The last consideration is of great interest. For it appears that in general the exaggeration of various structural features is indicative of important biologic changes in that particular zoological group in which such extreme developments take place; and as has been shown in other orders this extravagant and undue acceleration in growth is relatively very rapid, but of short duration, and usually terminates in the abrupt extinction of the group; or as in some cases results in a very great diminu-

* *Vide* Wachsmuth and Springer, Transition Forms in Crinoids, Proc. Acad. Nat. Sci. Phila., 1878.

† Jour. Boston Soc. Nat. Hist., vol. vii, pp. 224, 225.

‡ Loc. cit.

tion of vitality. It would seem then that a general amplification of the various anatomical structures in any faunal group marks its culmination; and this fact is peculiarly significant in its application to fossil crinoids, for the middle of the Lower Carboniferous was preëminently the climax of crinoidal life.

The abrupt extinction of a large proportion of crinoidal forms towards the close of the Keokuk is certainly suggestive of a series of decided and wide-spread changes in the geographic and bathymetric extent of the great interior sea. White* has already shown that at least in some portions of the Mississippi basin there were very considerable alterations in the coastal contour of this broad shallow gulf, during the latter part of the Lower Carboniferous; and it is known that there were even greater changes in the coast line in other parts of this region during the same period. During the Keokuk the waters over portions of Iowa, Illinois, Missouri and Indiana became greatly diminished in depth and the land of the same area was considerably extended. While the St. Louis beds were being deposited the sea again encroached upon the land, extending in some places more than two hundred miles northward beyond the former Keokuk waters. Over an extensive portion of the interior sea the conditions of environment during the Keokuk and St. Louis epoch presented some notable differences, as is amply attested by even a casual comparison of the faunæ of the two divisions. In some parts of Indiana and Illinois the organic remains of the former are characterized by a certain luxuriancy of individual growth, apparent not only in one, but in the majority of the zoological groups represented. In the latter division the animal forms, in many cases, are strikingly depauperate. It is not only a depauperation among a few types that is discernible, but a great diminution in vitality is manifest in forms genetically related to those occurring in the Keokuk.

The Lower Carboniferous of the Appalachian area seems to present two easily determinable divisions. In the Mississippi basin this double nature of the Lower Carboniferous does not appear to be clearly defined. The combined physical and paleontological evidence would indicate that the Lower Carboniferous throughout the interior of North America is broadly divisible into three sections; the lower comprising chiefly shales and sandstones, and the two upper principally limestones. If, in the correlation of the Lower Carboniferous strata of the Appalachian and Mississippi regions, the latter is to be considered double as the former it does not appear advisable to draw the line of division between the Burlington and Keokuk, for reasons already stated. In accordance, there-

* Geology Iowa, vol. i, p. 225, *et seq.*

fore, with the salient statigraphical and faunal features as presented, the evidence in considering the dual character of the Lower Carboniferous in the continental interior indicates that by far the two most widely separated of the five generally recognized divisions are the Keokuk and St. Louis.

Recapitulating, it appears that in the Lower Carboniferous of the Mississippi basin: (1) the most characteristic faunal group was preëminently dual in its general aspect, the Crinoidea greatly predominating during the first part, and the Blastoidea during the latter portion, of the period; (2) that a large proportion of the genera of echinoderms became extinct toward the close of the Keokuk; (3) that, of the crinoidal genera represented in the St. Louis and Chester, nearly one half of the number did not occur in the earlier epochs; (4) that among the Crinoidea in general the abrupt and extensive differentiation in certain anatomical features toward the end of the Keokuk are suggestive of decided changes in the biological and physical conditions of environment; (5) that the faunas of the Burlington and Keokuk are very closely related genetically, the two being practically continuous; (6) that if the members of the Lower Carboniferous of the Mississippi basin are to be synchronized with the two divisions of the Appalachian Lower Carboniferous, the line of demarkation is far more apparent at the close, than at the beginning, of the Keokuk epoch.

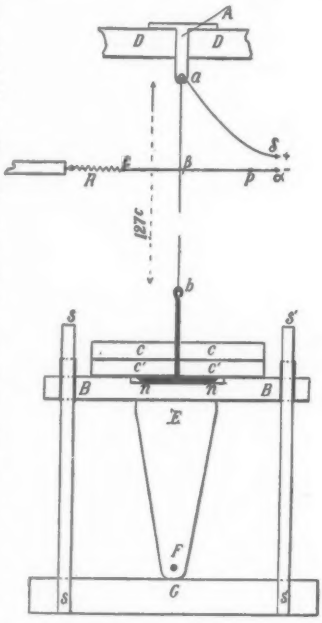
ART. XXV.—*The Energy Potentialized in Permanent Changes of Molecular Configurations;* by CARL BARUS.*

1. IN the following work a soft annealed wire is stretched by a known weight falling from an initial position (strain minimum), to the lowest position compatible with the given adjustment (strain maximum). If the wire remains sufficiently soft throughout the experiment the recoil is nearly zero. Hence the energy expended in stretching is to this extent easily measurable; and if also the heat evolved during stretching, be measured, the difference between the work done on each centimeter of wire and the heat produced per centimeter of wire is the energy potentialized; i. e. the energy which permanently manifests itself as tensile strain. Using the nomenclature of Maxwell's theory of viscosity, the numerical datum, thus obtained, is an expression for the amount of change in the history of the typical molecular configuration, the dates being taken immediately before and immediately after the tensile stress is applied.

*In my paper, this Journal, xxxvii, page 346, Table II, exchange traction and torsion. In the fourth line below read conductivity for resistance.

Now it is clear that the strain-effect of a given amount of work done must depend on the dimensions of the material. It must be supposed variable with the extension produced in case of a given sectional area, as well as with the section of the stretched wire in case of a given extension. At the outset it is difficult even to conjecture in what respect these strains, though of a given class, may differ in essential details. There is, however, a more interesting phase of these experiments: the strain-effect of a given amount of work done on centimeters of wire will vary, cæt. par., with the material acted upon. From this point of view the prosecution of the present research promises to lead to results bearing directly on the nature (form and mutual relations) of the molecules sustaining strain.

2. In figure 1, $CC\ C'C'$, the weights (P=40 kg to 60 kg) by which stretching is to be done are supported on a suitable trap-door, BB; and the fall of BB, when released, is guided by the upright slides ss, $s's'$, fixed in the firm base, G, of the apparatus. I took pains to adjust the soft wire ab to be acted on, as nearly straight and free from initial tensile strain as possible. It was firmly fastened above to a heavy cross-timber of wood, DD, the lintel of a framework which in form and purpose closely resembled a gallows. The screw clamp at a in the vertically adjustible brass torsion-circle A, the axle of which passes snugly through DD, secures the upper end of the wire. The lower end is lapped around the hook of the weight pan, bnn, then wound around the wire and soldered, care being taken to avoid such loops and kinks as might change form during stretching.



A thermo-couple, $\alpha\beta\alpha\delta$, originally of platinum/platinum-iridium, with its junction β tied on with silk thread on the upper half of the wire ab, enabled me to measure the change of temperature due to stretching. In later experiments more reliable devices were adopted, cf. § 5. Changes of length were measured with Grunow's cathetometer, two fiducial marks having been painted on the wire ab about 70 ^{cm} apart. At a given signal the

catch-board EF of the trap-door BB was jerked away, by aid of a rope tied at F and manipulated by an assistant.* Simultaneously with the stretching I read off the temperature-increment in terms of the excursion of the needle of a sensitive mirror-galvanometer, and as soon as this was taken, I made the final length measurement with the cathetometer. From these both δL and δl, i. e. the length-increment of the whole wire and of the part between the fiducial marks, respectively, were derived. δL varied between 8^{cm} and 20^{cm}, δl between 6^{cm} and 11^{cm}, L being about 12^{cm}.

3. In Table 1, I have systematized the results of the measurements. Here ρ_s and ρ_h denote the radii of the wire before and after straining, and are computed from gravimetric measurements. P is the stretching force; $\delta l/l$ the longitudinal extension produced, and measured between fiducial marks on the wire with the cathetometer. $E = P\delta L/L = P\delta l/l$ is the work done on centimeter of length; t the observed increment of the temperature of the wire resulting. Finally $r = E_t/E$ indicates the part of the applied work which is converted into heat, the remainder $(E-E_t)/E$ being potentialized. The table contains both $P\delta L/L$, and $P\delta l/l$, the latter being usually greater in consequence of errors of experiment which need not here be considered.

The heat corresponding to $t°$ being $Amct$, where A is the mechanical equivalent of the water-gram-degree in ergs, m the mass of the wire per centimeter and c its specific heat. I was obliged to take c from tables and also for want of data to disregard the variations of c during straining. Density, Δ, was measured before and after stretching.

TABLE 1.—*Energy potentialized in tensile strains. First method.*

Metal	$2\rho_s$ / $2\rho_h$	P	$\delta l/l$	$P\delta L/L$	$P\delta l/l$	t	$r = E_t/E$
	cm	g	(cm)	megalergs	megalergs	°C	
Brass	·1662	60,000	·129	7·5	7·7	4·3	0·40
$\Delta = 8·42$	·1546		·163	9·3	9·8	4·1	·30
			·151	9·0	9·1	3·9	·31
			·168	9·9	10·1	4·3	·31
			·153	9·1	9·2	6·0	·45
			·160	8·9	9·6	7·0	·52
Mean			·154	8·95	9·24	4·9	·38
Iron	·1362	50,000	·087	4·26	4·35	3·8	0·47
$\Delta = 7·68$	·1310		·091	4·33	4·56	4·0	·47
			·084	4·17	4·22	4·3	·54
			·087	4·26	4·36	3·5	·43
Mean			·0875	4·25	4·37	3·9	·48
Copper	·1630	40,000	·147	5·58	5·88	6·0	0·77
$\Delta = 8·87$	·1514		·148	5·51	5·92	5·1	·65
			breaks	----	----	5·5	----
			·153	5·90	6·12	5·3	·65
Mean			·149	5·66	5·98	5·5	·69

* Mr. Ernest L. Howard had the goodness to give me much efficient service during the course of the present experiments.

4. A few words on the errors involved are essential. Comparison of the values of $P\delta L/L$ and $P\delta l/l$ shows that the work lost upon kinks and flaws together with that spent upon the frame-work is not seriously large so far as the present purposes are concerned. This is also true of the energy elastically potentialized, as may be found by direct tests. The satisfactory measurement of the thermal datum t, however, is much more difficult. Apparently the graduation of the thermo-couple is simple: for it is merely necessary to make preliminary observation of the throw of the needle of a ballistic galvanometer produced by given increments of temperature. The use of such graduation is, however, only permissible if the temperature of the wire remains constant during the period of oscillation of the needle. These conditions are never rigorously given; whereas even in case of jacketed wires it is a question whether they are sufficiently given. The temperature of the wire increases very rapidly to a maximum, and then decreases by radiation, etc., reaching the original thermal value in a few minutes. Again the cooling effect of the metallic wires of the thermo-couple cannot easily be allowed for, neither can it be considered negligible even in case of filimentary wires. Finally the error of heterogeneity is of serious consequence; for the thermoelectric measurement is virtually a thermal exploration of the metal lying very near the point-junction. Hence since the wire near such a point may be imperfect by reason of flaws or composition so that more or less work is done here than at other parts of the wire, it follows that the temperature thermo-electrically obtained is not a mean datum for the wire taken as a whole.

Unfortunately the combined effect of the errors stated will usually be the cause of too small a value of t. Some assurance of the approximate truth of the results in Table 1 may, however, be obtained by observing that the experiments made are to some extent differential in kind. For instance, caet. par., about as much heat is evolved in the copper wire for an expenditure of only $\frac{2}{3}$ the work applied to the brass wire. Sections and thermo-couple are here the same and similarly adjusted.

The importance of the thermal datum is such, however, that special corroborative measurements are essential. To obtain these, the above method was modified in such a way that the wire was stretched successively in equal amounts. One end of it was fixed and the other fastened on the circumference of an iron drum of small radius, $\rho = 0{\cdot}9^{cm}$. By revolving the latter the wire is stretched and the friction of the axle sufficient to keep it so. I chose successive angles of revolution, π, by which extensions $\delta L/L = {\cdot}054$ each, were easily produced, and could usually be repeated 4 or 5 times.

The results of these experiments showed no essentially new points of view. Hence I will omit them in favor of the work of the next paragraph.

5. The errors discussed in § 4 induced me to repeat the work with a thorough change of method, so far as the thermal measurements are concerned. To obtain the data of table 2, the thick wire *ab*, figure 1, was itself used as one of the elements of the thermo-couple. The other element was a filimentary wire $a\beta\varepsilon$, passing from a fixed point p in connection with the terminal of the galvanometer, once around the wire to be stretched (junction, β), and thence to an insulated spiral spring, R, to keep it tense. At the point, β, where the thin wire lapped around the thick wire, both were carefully brightened and good electrical contact was further insured by stiffening the spring R as much as the thin wire permitted. The upper end a of the wire to be stretched placed in connection with the other terminal δ of the ballistic galvanometer completed the circuit. In this way the heat generated by stretching acts at once at the thermoelectric junction of the thick and the filimentary wire, while the latter may be chosen so thin as to produce only negligible cooling. Indeed in virtue of friction the discrepancy is apt to be in the opposite direction.

In this arrangement* a special error is introduced by the change of thermoelectric constants due to stretching, but this error, for the present purposes at least is negligible in comparison with the thermoelectric powers copper/ iron, or brass/ iron, being not greater than a few per cent.

The notation of table 2 is the same as that in table 1. E_p the mean energy stored in the wire per centimeter of length has been added.

TABLE 2.—*Energy potentialized in tensile strains. Second method.*

Metal	$2\rho_s$ / $2\rho_h$	P	dl/l	E	t	E_t/E	E_p
	cm	g	(cm)	megalergs	°C		megalergs
Brass	·166	60,000	·199	11·8	9·1	0·55	5·0
	·155		·191	11·5	9·0	·56	
			·182	10·9	8·8	·58	
Copper	·163	40,000	·153	6·12	6·8	0·81	1·3
	·151		·153	6·12	6·1	·72	
			·153	6·12	6·8	·81	
			·143	5·72	6·0	·76	
			·143	5·72	6·3	·80	
Iron	·136	50,000	·084	4·21	4·0	0·51	2·2
	·131		·086	4·28	3·9	·49	
			·089	4·47	4·3	·51	
Iron	·136	40,000	·032	1·26	0·8	0·36	0·9
			·031	1·23	0·5	· 22	

* After making these experiments, I found that a similar method of thermoelectric measurement has recently been employed by Wassmuth (Wiener Sitzber., xcii, (2), p. 52, 1888). Wassmuth's purposes are distinct from mine.

A comparison of the results of table 2 and table 1 shows that the latter substantiates and emphasizes the results of the former. In table 2, moreover, the measurements of the effects produced by stretching the same metal are in very much better accord. It is not improbable that the variations of E_t/E for the same metal in table 2 may be due to actual differences of hardness or composition of the annealed wires.

In case of iron two values of P occur, and the metal exhibits striking differences of behavior in the two experiments. It appears that more energy is potentialized during initial than during final stages of strain. For $P = 40$ kg, the small value of t is only measurable as a superior limit. Moreover the extension is here so small that the error due to resilience may be 5 per cent.

6. To summarize it appears that as much as one-half of the work done in stretching up to the limit of rupture may be stored up permanently; that the amount of work thermally dissipated varies considerably with the metal acted upon, being very large for instance in case of copper (75 per cent), smaller in case of brass (60 per cent) and of iron (50 per cent); that in case of the same given metal the work done is very largely potentialized during incipient stages of strain, and very largely dissipated during final stages of strain. When stress of a given kind is applied to different metals, the total amount of energy which can be stored per unit of section, per unit of length up to the limits of rupture, may therefore be looked upon as a molecular constant of the metal. Table 2 shows that in case of a wire about $\cdot 16^{cm}$ thick stretched nearly to the limits of rupture, at least 5 megalergs per centimeter will have been stored in case of brass, and about 1 megalerg per centimeter in case of copper. In iron $\cdot 14^{cm}$ thick at least 2 megalergs per centimeter are potentialized under the same conditions.

ART. XXVI.—*Contributions to Mineralogy, No.* 44; by F. A. GENTH.

1. *Gadolinite.*—In the fall of the year 1888, Dr. A. E. Foote sent me for identification a shining black mineral which he brought from Burnett County, Texas. A preliminary examination, which I made, proved it to be *Gadolinite*, which, excepting that from Colorado, described and analyzed by Mr. L. G. Eakins of the U. S. Geological Survey, had never been observed in this country. Since it became known that the mineral brought from Texas by Dr. Foote was gadolinite, large quantities have been obtained, some in crystals, weighing from

seven to eleven pounds. I am indebted to Mr. W. Earl Hidden for some from Llano County, Texas, and give in the following the results of my analyses of this, as well as that received from Dr. Foote.

It has a black color; in thin splinters it is translucent with a dark bottle-green color; the fine powder is greenish-gray; fracture conchoidal to splintery. Sp. gr.=4·201 (Burnett Co.) to 4·254 (Llano Co.). Heated to low redness, it begins at once to glow vividly through the whole mass and swells up into ragged fragments of a grayish-white color, only superficially melted. The fine powder is soluble in dilute acids, even after ignition. The best solvent I found to be dilute sulphuric acid (1 : 20) in which it dissolves in the cold after repeated shaking, leaving only a minute, somewhat flocculent, reddish residue of ferric oxide and a little quartz which were mechanically mixed with the gadolinite.

The Texas gadolinite is altered into a brownish-red mineral of waxy luster, finally into a reddish or yellowish-brown earthy substance. Neither could be obtained in a state of purity, but I will give below a partial analysis of the former. *Tengerite* (?) or yttrium carbonate in thin, white crystalline incrustations is found between the cracks of the gadolinite. There was only enough obtainable to show their composition by qualitative tests.

In the analyses of the Burnett Co. gadolinite I, *a* and *b*, it was dissolved in hydrochloric acid, in those of the Llano Co. mineral II, *a* and *b*, in dilute sulphuric acid and the mechanically admixed ferric oxide and silica separated by filtration. The other separations were made in the usual manner. The cerium oxide was separated from the oxides of didymium and lanthanum by oxydizing the almost neutral nitric acid solution with bromine, and precipitation of the boiling solution with sodium acetate. This was repeated five times, when, finally, the filtrate gave only traces of oxides which could be precipitated with oxalic acid and the ceric oxide showed a pale salmon color. The oxides, separated from the cerium were chiefly didymium oxide, and lanthana in smaller quantity. The oxides of the metals of the yttrium group gave almost white salts, with only a very faint rose color of that of erbium. The separation of glucina and alumina from ferric oxide was effected from a solution of citric acid and ammonia by precipitating the iron as ferrous sulphide, which method I found to give the most satisfactory results. The little alumina was separated from the glucina by precipitating the nearly neutral solution and re-dissolving the precipitate in a strong solution of sodium hydrate and, after the dilution with much water, precipitating the glucina by continuous boiling. After acidu-

lation of the alkaline solution the alumina was precipitated by ammonium hydrate. The alumina, separated in this manner, after dissolving it in hydrochloric acid, and treatment of this solution with sodium hydrate, did not yield a trace of glucina on continuous boiling of the dilute alkaline solution.

The following results were obtained:

	I. Burnett County.		II. Llano County.	
	a	*b*	*a*	*b*
SiO_2	22·87*)	23·40*)	22·80	22·92
Al_2O_3	0·28	0·33	0·31	0·29
Ce_2O_3†)	2·65	2·76	2·66	2·85
$(Di,La)_2O_3$	5·22	5·17	5·01	5·33
$(Y,Er)_2O_3$	44·35	44·65	44·45	44·30
MnO	0·22	not det.	0·18	not det.
FeO	13·69*)	13·58	12·93	13·03
BeO	9·24	9·32	9·19	9·34
MgO	0·07	0·08	0·11	not det.
CaO	0·64	0·54	0·71	0·78
Na_2O	0·20	not det.	0·23	not det.
K_2O	0·15	" "	0·12	" "
Ignition	0·72	" "	0·79	" "
Insoluble in dil. H_2SO_4	not det.	" "	0·93	0·92
	100·30		100·42	

Decomposed Gadolinite from Llano Co.

Spec. grav.	= 3·592
Ignition	9·30
Quartz	1·03
SiO_2	22·11
$(Ce,Di,La,Y,Er)_2O_3$	39·20
Fe_2O_3	14·53
BeO	6·03
MnO	0·22
CaO	5·58

2. *Cacoclasite.*—At the meeting of the Mineralogical and Geological Section of the Academy of Natural Sciences of Philadelphia, November 26th, 1883, the late Professor H. Carvill Lewis described under the provisional name "cacoclasite," peculiar white and grayish-white crystals, imbedded in blue cleavable calcite, associated with graphite, pyroxene, wollastonite, cubical spinel, pyrrhotite, etc., at Wakefield, Ottawa County, Quebec, Canada. They are nearly square prisms with truncated angles, the general appearance being

* Includes the Fe_2O_3 and SiO_2, insoluble in dilute sulphuric acid.

† Mr. L. G. Eakins informed me that he had found ThO_2 in the Texas gadolinite. As I had not tested for it, I examined the ceric oxide, left from the four analyses, and found it to contain 3·22 per cent of ThO_2.

that of a partly altered scapolite. They are tetragonal with $O \wedge 2 = 129\frac{1}{2}°$. The following planes have been identified: *O*, *i*-*i*, 2, 2-*i*, 2-2, 6-3, the last two hemihedral. Almost entire absence of cleavage, luster vitreous to resinous; H.=5–6; Spec. gr.=3·050–3·057.

An analysis, made by Mr. Reuben Haines gave, after deducting admixed calcite:

		Oxygen ratio.	
SiO_2	= 36·74	0·612	= 6
Al_2O_3	19·79	0·190	2
Fe_2O_3	1·33		
CaO	38·16	0·736	7
MgO	0·77		
Na_2O	0·32		
K_2O	0·17		
P_2O_5	2·49		
H_2O	0·23		

Quantivalent ratio of bases (*in which he includes* P_2O_5—F. A. G.) to SiO_2=9 : 6=3 : 2, thus making the mineral a subsilicate.

Professor Lewis concludes his article thus: "The species appears to be isomorphous with sarcolite, but its very different physical and chemical characters indicate either a distinct species or a pseudomorph. The absence of cleavage and the heterogeneous microscopic characters argue pseudomorphism. Chemically it is allied to gehlenite. The temporary name 'cacoclasite,' referring to its imperfect cleavage was suggested. The specimens are still under investigation."

I have no information that anything in addition to the above was done by Professor Lewis, and as the whole tenor of his communication leaves a great deal of doubt about the nature of this mineral, I have, at the suggestion of Professor G. Christian Hoffmann, chemist and mineralogist of the Canada Geological Survey, made a few experiments with excellent material which he had given me for this purpose, also with a crystal which Dr. A. E. Foote kindly presented to me, and give in the following the results of my investigation.

The calcite, in which the cacoclasite crystals are imbedded, is of a pale blue color and shows perfect cleavage, producing cleavage crystals up to 10^{mm} in size; the cacoclasite crystals vary from 3^{mm} to about 50^{mm} in diameter; their surface is glossy and has the appearance, as if the crystals had undergone a partial melting or vitrification. They are more or less rounded, the planes, *without exception*, are not smooth but deeply corrugated and grooved in an irregular manner. It is remarkable that this peculiarity must have existed, before the

calcite was deposited upon the same, because, when broken off from the cacoclasite, it shows the reverse of the grooves and corrugations of the latter.

For investigation two crystals were used, the best one of Professor Hoffmann's (I) about 12^{mm} in size, was almost white, but had a little pyrite in the center, that from Dr. Foote, (II) about 18^{mm} long had a slightly brownish white color, but the interior was of a uniform grayish white color. Finely granular, like sugary quartz and of the same luster, crystal I was slightly coarser than II. Spec. grav. of crystal I=3·337, of crystal II =3·222.

They were broken into small fragments from 2 to 3^{mm} in diameter and carefully examined for their purity, but none showed any admixture of blue calcite or other minerals.

By qualitative analysis it was found that although no calcite could be found by a strong lens, both crystals contained a carbonate, probably that of calcium, a phosphate, probably apatite, and a considerable quantity of *free* quartz. In the quantitative analysis the latter was determined by fusing the finely powdered mineral with microcosmic salt, dissolving in hydrochloric acid and boiling the remaining silica with dilute sodium hydrate, as long as it extracted soluble silica.

In crystal I the remaining SiO_2 was 23·44 per cent; this on being fused with sodium carbonate etc., etc., gave *pure* SiO_2= 23·04 per cent present as *quartz*, with little alumina and calcium oxide. Crystal II treated in the same manner gave 11·84 per cent of silica which contained 11·63 per cent of *pure* SiO_2 present as *quartz*. The analyses gave the following results:

		I.	II.
H_2O	=	1·04	2·28
CO_2		6·73	4·25
SiO_2		31·52	32·67
P_2O_5		2·19	3·36
Al_2O_3		17·34	19·63
Fe_2O_3		0·51	0·39
MgO		trace.	0·49
CaO		40·95	36·38
Na_2O		trace.	0·31
K_2O		trace.	0·20
		100·28	99.96

Deducting the CO_2 as calcium carbonate, the P_2O_5 as apatite and the free quartz, we get:

$CaCO_3$	=	15·20	9·66
$Ca_5F[PO_4]_3$		5·05	7·74
SiO_2		23·04	11·63
Apparent admixtures		43·29	29·03

The remaining constituents would give the following composition:

	I. Molecular ratio.			II. Molecular ratio.		
H_2O =	1·83	0·102	= 2	3·22	0·179	about 3
SiO_2	14·89	0·248	5	29·67	0·495	8
Al_2O_3	30·45	0·296	6	27·68	0·270	5
Fe_2O_3	0·90	0·006		0·55	0·004	
MgO	....			0·69	0·017	12
CaO	51·93	0·927	18	37·47	0·569	
Na_2O	....			0·44	0·008	
K_2O	....			0·28	0·003	
	100·00			100·00		

Although these analyses, especially I, show a simple molecular ratio between the constituents, they do not represent the constitution of any known mineral and are evidently mixtures, the actual nature of which, however, we have no means to determine. From all this, cacoclasite cannot be considered a good species, but a mixture of quartz, calcite, apatite and other unknown minerals in various proportion, which have the form of scapolite and have resulted from its alteration.

3. *Monazite.*—At the Villeneuve Mica Mine, Ottawa County, Quebec, Canada, an interesting variety of monazite has lately been discovered, of which Professor G. Ch. Hoffmann sent me a specimen.

It has a reddish-brown color, indistinct cleavage and little or slightly waxy luster. The specific gravity of the purest cleavage pieces was found to be =5·233. The analysis gave:

H_2O	= 0·78
SiO_2	0·91
ThO_2	12·60
P_2O_5	26·86
Fe_2O_3	1·07
Ce_2O_3	24·80
$(LaDi)_2O_3$	26·41
$(YEr)_2O_3$	4·76
MgO	0·04
CaO	1·54
	99·77

Chemical Laboratory,
Philadelphia, 111 S. 10th st., April 29, 1889.

ART. XXVII.—*On the Period of Rotation of the Sun;* by HENRY CREW, Ph.D., Instructor in Physics in Haverford College.

PETERS* was probably as early as anyone to remark that the period of rotation of the sun, without farther limitation, was a meaningless term. In a series of observations on sun spots, taken at Naples during the years 1845–6, he found, among his results, discrepancies larger than could be explained by errors of measurement; but what is more striking, these discrepancies were always in one direction. In short, he showed that each heliocentric latitude has its own period of rotation.

The law, according to which this velocity varies with the distance from the equator, Carrington† has placed beyond doubt. His work, however, is all confined to the photosphere or the immediately underlying region in which the sun spots have their seat.

A few years later Braun and Hornstein,‡ independently, discovered in the magnetic elements a pretty well marked variation, having a twenty-six-day period. This at once suggested a means of getting the rotation period of the solid (?) nucleus of the sun. For Braun (Phil. Trans., 1876), from two years' observations, finds that the large disturbances of the horizontal component of the earth's magnetism were nearly all confined to the days on which one of three solar meridians was presented to the earth. But this needs confirmation, for the total number of disturbances observed was not large. However, the *phase*§ of this disturbance, unlike those of the annual and secular variations, is the same in all parts of the earth, seeming to indicate that we have here to deal with solar action which is direct and not intermediate. On the other hand, solar temperatures appear to preclude the possibility of the sun being a permanent magnet. So that the region of sun whose period Braun and Hornstein and, later, Liznar,‖ have determined remains completely unknown, but with the probability of its being below the photosphere.

A fairly pronounced twenty-six-day variation in the daily range and height of both the thermometer and the barometer has been known for a long while. But no theory, in any degree tenable, has been offered to explain the connection of this variation with the sun. We are, therefore, also unable to assign this period to any definite solar height. But there are reasons (Encycl. Brit., art. *Meteorology*) for thinking that it is the rota-

* Proc. Amer. Assoc. Adv. Sci., ix, p. 87, 1855.
† Carrington, Observations on Solar Spots, London, 1863.
‡ Hornstein, Ber. Akad. Wien., lxiv, p. 62, lxvii, p. 385, 1873.
§ Braun, C. R., lxxvi, p. 698.
‖ Liznar, Ber. Akad. Wien., Bd. 91, p. 454.

tion period of the same part of the sun as that given by magnetic variations. In this case the three particularly active solar meridians, discovered by Braun, would appear to be essentially regions of great thermal, rather than magnetic, activity. That these variations are due primarily to the direct heating effect of the sun is the basis on which Faraday, Christie, De la Rive, and Stokes have each with varying success explained the subject of terrestrial magnetism.

But if the rotation period is to be determined from barometric and magnetic disturbances, then regions of special solar activity must be assumed to be persistent. Evidence of this from other sources is doubtful, though the observations of Sporer on sun spots and Wilsing on faculæ would seem to indicate that these outbursts have a tendency to recur at the same place

Doppler's principle has already been applied by Zöllner, Vogel, and Young, to the determination of the relative velocities of the extremities of a solar diameter. Here we have under investigation probably a different part of our luminary, viz: the seat of selective absorption for the Fraunhofer lines, a layer of considerable thickness mixed up with and extending into the photosphere. So that this method probably gives the period of a region higher than that of the sun spots.

Later, Wilsing,* of Potsdam, has measured, by means of photography, the daily angular motion of a large number (1012) of persistent faculæ. Since these are seen as elevations in passing over the sun's limb and give brighter spectra† than surrounding portions of the solar surface, there is reason for thinking that the period thus obtained by Wilsing is that of a region some distance above the photosphere.

There are, then, at least four distinct solutions of the problem in hand:

(*a*) The observation of sun spots, giving the period of the lower parts of the photosphere for various latitudes. The data in our possession are here limited to a zone extending a little less than 45° on each side of the equator.

(*b*) The observation of the meteorological (including magnetic) elements, giving the period of an unknown region, possibly of the more solid interior, possibly of the region of the great uprushes around the spots.

(*c*) The measurement of the difference of refrangibility of light coming from the eastern and western limbs of the sun, suggested by Zöllner.

Since the accuracy of this method varies as the cosine of the latitude, observations are, at present, of no value for parallels higher than 75°.

* Wilsing, Publicationen des Astrophysikalischen Observatoriums, 1884.

† Lockyer, Chemistry of the Sun, p. 105.

(*d*) The observation of faculæ, giving the period for a layer probably a few hundred miles higher than the photosphere. Present data extend from 24° S. to 33° N.

Each of these methods gives the synodic period.

The object of the work communicated in this paper is to measure the rotation for a zone some 60° wider than any hitherto observed, and to verify or disprove the conclusion which appeared to follow from some observations made a year ago.* The measurements then at hand gave for the daily angular motion, θ, of any point on the sun's absorbing layer, as a function of the heliocentric latitude, χ,

$$\theta = 838' \, (1 + 0{\cdot}00335 \, \chi),$$

which makes the velocity a minimum at the equator, the place at which, for sun spots, it is a maximum.

There was also, apparently, a systematic error† in the first series, depending either upon the heating of the spectroscope or upon some cause which varied with the date of observation. This, I hope, has been eliminated in the second set of measurements, which are here given.

They were made with the same instrument, viz: the large spectrometer of the Johns Hopkins University, but with the three modifications which follow.

The method of shifting the sun's image across the slit was so changed that almost any solar latitude could be observed at any time.

This was accomplished by a device suggested by Professor Rowland. The brass ring which held the condensing lens was furnished with a metal arm, not unlike the handle of a palm-leaf fan. This arm was pinned to a brass collar, larger than the lens and surrounding it. This pin was the axis, parallel to the optical axis of the lens, about which the lens rotated through a small arc, throwing the image of the sun, now with its eastern, now with its western, limb on the slit. But this collar, besides having adjustable stops to limit the motion of the lens, could also be rotated in its own plane, and clamped in any azimuth, thus changing the direction of the motion of the image across the slit. To make this latter change was the only purpose of this part of the apparatus. For a reflecting prism was inserted between the condensing lens and the collimator, and by rotating this, any desired portion of the sun's limb could be made tangent to the slit. This having been done, the image would, in general, no longer move at right angles to the slit; so the device above described was used to counterbalance the effect of the prism on the

* Crew, this Journal, Feb., 1888.

† Discussion of this in Observatory, April, 1888.

direction of motion. The prism was by Steinheil and gave very perfect definition.

The Fahrenheit heliostat, with two mirrors, used in the first series, was replaced by a better instrument of the Foucault pattern.

Two of Professor Rowland's gratings were used. That designated as "No. 1," I had used before. It was four inches long, ruled with 14,436 lines to the inch, and gave superb definition in the 4th order. The other, "No. 2," was a six-inch grating, with 7218 lines to the inch, and gave fair definition in the 8th order.

The objectives of the collimator and telescope had each a clear aperture of six and one-half inches. The angle between their optical axes remained constant, the grating being movable.

In the first series, the grating was so placed that its normal and the diffracted ray were both on the same side of the incident ray, a position which shall be denoted by "right;" while, in the second series, the normal and the diffracted ray were on opposite sides of the incident ray, a position called "left." This change, as we shall presently see, has a very decided effect on the result.

The method of observation was very simple. The adjustment of the instrument having been tested as accurately as could be, by setting on an atmospheric line, the cross hairs were then set on the solar line whose displacement was to be measured, and the micrometer read. The sun's image was then shifted by a cord convenient to the observer at the eyepiece, and the micrometer read for the opposite limb. Ten settings of this kind were made in succession, and then a new latitude was chosen.

Formula.

The value of the relative linear velocity of the two limbs at the equator, $v'-v''$, was computed from the following formula which, together with the method of obtaining the heliocentric latitude, was sufficiently discussed in connection with the first series.*

$$v'-v'' = \frac{c\ V\ \Delta}{\lambda \cos\chi} \cdot \frac{1}{\cos h} \cdot \frac{\sqrt{1-\sin^2\chi\cos^2\chi}}{\cos\chi\ \cos\theta} + 2\alpha \sin\varphi$$

* Professor Oliver has been kind enough to call my attention to an error in the formula as used in the computation of the first series, viz: the omission of the factor "2" from the last term of the right-hand member, the effect of which was to make the result there given some three per cent smaller than it should have been.

The corrected value from the *previous* measurements is

$$v'-v'' = 2{\cdot}565 \text{ mi. per sec.}$$

and daily angular motion at equator = 838′.

Where
- c = value of one revolution of the micrometer screw in Ångström's units.
- V = velocity of light, in miles per second.
- Δ = displacement measured in micrometer revolutions.
- λ = wave length of line whose displacement is measured.
- χ = heliocentric latitude.
- h = half the angle subtended at the center of the sun's image by that portion of the slit covered by the sun's image.
- θ = inclination of the plane of the solar equator to the ecliptic.
- φ = angular semi-diameter of the sun as seen from the earth.
- α = linear velocity of the earth in its orbit, in miles per second.

Observations.

The following table includes all the observations made, except three in which a radial slit was used. The difficulty of setting on the end of such a line is so great that these have been discarded, and only those made with a tangential slit are retained.

These observations are arranged in the order of their solar latitudes, given in column 7.

Column 6 gives the difference between the readings of the micrometer, on the eastern and western limbs of the sun respectively. The relative equatorial linear velocities, computed from the above formula, will be found in column 8.

In column 9 is given the average discrepancy (in per cent) among themselves of the ten settings which make up each observation. May it not be that local currents—solar gusts—have something to do with the large irregularities in this column?

Column 10 gives the quadrants in which lay the extremities of the solar diameter under observation. This, together with the latitude, completely determines the points at which the slit was made tangent.

Each weight in column 11 is the product of the cosine of the latitude by a number depending on the definition and the grating, and was determined from notes taken at the time of observation.

Six of the observations were made by Mr. Louis Bell, Fellow in Physics of the Johns Hopkins University; the others by the writer. Neither of us, at the time, had the slightest idea in what latitude we were observing. The value of the mean relative equatorial velocity thus obtained is

$v'-v''=2{\cdot}173 \pm 0{\cdot}028$ mi. per sec.,

a velocity some 15 per cent less than that obtained in the first series, viz: 2·565 mi. per sec. But this, as Professor Young has

TABLE I.

1 No. of obs.	2 Date.	3 Mean time of obs.	4 Line.	5 Grating.	6 Displacement. Δ	7 Heliocentric latitude χ	8 $(v'-v'')-2\alpha\sin\phi$	9 Ave'g. discrepancy.	10 Direction of diameter measured.	11 Weight.
		H. M.			Rev.	°	M.p.sec	%		
1	July 6	12 12	5166·4	No. 1	0·0905	4·4	2·165	6	N.W.-S.E.	50
2	June 18	11 09	5914·3	2	0·1121	8·1	2·099	6	N.W.-S.E.	20
3	July 11	10 58	5166·4	1	0·0824	8·9	1·990	11	N.E.-S.W.	50
4	June 19	11 36	D_1	1	0·1076	14·3	2·100	13	N.W.-S.E.	10
5	"	11 50	"	"	0·1116	15·2	2·187	11	N.W.-S.E.	20
6	July 6	11 54	5166·4	"	0·0843	16·3	2·095	8	N.W.-S.E.	40
7	July 3	11 24	5914·3	"	0·1089	17·5	2·188	10	N.W.-S.E.	20
8	June 18	11 52	"	2	0·0990	18·3	1·932	12	N.W.-S.E.	20
9	June 16	11 33	D_1	"	0·1224	18·5	2·410	14	N.W.-S.E.	10
10	July 11	10 39	5166·4	1	0·0764	21·9	1·966	11	N.E.-S.W.	45
11	June 19	12 14	D_1	"	0·0993	24·0	2·056	9	N.W.-S.E.	18
12	July 3	11 36	5914·3	"	0·1023	24·3	2·150	14	N.E.-S.W.	27
13	July 3	12 24	"	"	0·1050	24·4	2·210	15	N.W.-S.E.	36
14	June 18	10 56	"	2	0·0881	24·8	1·799	12	N.W.-S.E.	18
15	July 3	12 36	"	1	0·0995	25·1	2·106	12	N.W.-S.E.	27
16	June 18	12 06	"	2	0·0966	25·6	1·985	8	N.W.-S.E.	18
17	June 19	12 54	D_1	1	0·1044	30·4	2·289	17	N.W.-S.E.	18
18	June 18	12 34	5914·3	2	0·0802	32·5	1·763	10	N.E.-S.W.	24
19	July 6	12 24	5166·4	1	0·0749	32·8	2·131	12	N.W.-S.E.	40
20	June 18	12 22	5914·3	2	0·0920	39·3	2·202	13	N.W.-S.E.	8
21	"	11 21	"	"	0·0871	39·6	2·101	10	N.W.-S.E.	16
22	July 3	11 10	"	1	0·0681	43·1	1·786	11	N.W.-S.E.	21
23	"	12 03	"	"	0·0866	43·6	2·291	11	N.E.-S.W.	14
24	July 11	1 06	5166·4	"	0·0415	45·7	1·420	23	N.E.-S.W.	35
25	June 18	1 45	"	2	0·0567	45·8	1·534	13	N.E.-S.W.	21
26	July 6	11 21	"	1	0·0625	49·6	2·300	6	N.W.-S.E.	36
27	"	12 56	"	"	0·0406	56·6	1·762	15	N.W.-S.E.	25
28	July 11	11 30	"	"	0·0414	57·1	1·824	18	N.W.-S.E.	25
29	June 18	1 32	"	2	0·0513	58·8	1·872	16	N.E.-S.W.	15
30	July 6	11 05	"	1	0·0457	58·9	2·112	15	N.W.-S.E.	25
31	June 19	12 45	D_1	"	0·0621	60·0	2·347	18	N.E.-S.W.	10
32	July 6	10 49	5166·4	"	0·0276	62·3	1·418	19	N.W.-S.E.	25
33	July 6	1 11	"	"	0·0248	72·1	1·932	30	N.W.-S.E.	18
34	July 3	10 58	5914·3	"	0·0300	72·7	1·941	25	N.W.-S.E.	9

pointed out, is just what one would expect, since all the settings of the *first* series were made with the grating "right," and all those of the *second* with the grating "left." For the heating effect of the sun on the slit-plate will, in the first case, introduce an error with a positive sign, and in the second case, with a negative sign; *but these errors will not be equal in amount.*

I attempted to detect any heating effect by observing atmospheric lines, and, failing to discover any motion when the image was rapidly shifted from one jaw of the slit-plate to the other, I conclude that this effect would be negligible in measuring the displacement. But this is not true, because, in the latter case, the sun has more time to heat the plate.

When we consider that, if the whole differences between the two results were due to the heating of the slit-plate, the displacement of an atmospheric line on the micrometer would be only $\frac{1}{1000}$ of the distance between D_1 and D_2, it will not be surprising that it was not detected by direct observation of the motion.

Without knowing what displacement of the slit by heat would be required to harmonize the two results, I computed the amount of this error as follows: Of two thermometers, placed one on either side of the slit, that in the sun's image indicated at the end of one minute (the average time of a complete reading), an excess of 10° C. over the other.

If the angle of incidence be denoted by i, the angle of diffraction by r, the order of the spectrum by n, the wave-length by λ, and the grating space by e, then

$$\sin i + \sin r = \frac{n\lambda}{e} = \text{constant}.$$

$$\therefore dr = -\frac{\cos i}{\cos r} di$$

where di is the *angular* displacement of the slit and dr is the resulting *angular* displacement at the micrometer. When the eastern limb of the sun was on the slit the displacement was always in a direction opposite to that when the western limb was observed, so that these effects were added. Not only so, but since the increment di is negative when the grating is "right," dr will be positive and the reading of the micrometer will be too large. If now the grating be turned "left," di will be positive, and hence the micrometer reading too small.

There were 20 revolutions of the micrometer to the centimeter, and the ratio of the focal length of the telescope to the collimator was 1·08; so that if we call the micrometer error dm and the *linear* displacement of the slit ds, then

$$dm = -20 \times 1{\cdot}08 \times \frac{\cos i}{\cos r} ds \text{ micrometer revolutions.}$$

The condensing lens had a clear aperture of 8^{cm} with a focal length of 135^{cm}, thus giving an image of $1{\cdot}25^{cm}$ diameter. The jaws of the slit-plate were of blackened brass, were a little wider than the sun's image, and expanded toward the slit. If we assume that the expansion took place throughout that part covered by the image, then for 10° C.:

$$ds = \pm 1{\cdot}25 \times 10 \times 0{\cdot}000019 = 0{\cdot}000238 \text{ centimeters.}$$

$$\therefore dm = \pm 0{\cdot}0052 \times \frac{\cos i}{\cos r} \text{ micrometer revolutions.}$$

For either grating in the position "right," the value of $\frac{\cos i}{\cos r}$ was approximately, for all lines observed, 0·84.

$$\therefore dm = + \overset{\text{rev.}}{0{\cdot}0044}$$

But in the position "left," $\frac{\cos i}{\cos r} = 1{\cdot}19$,

$$\therefore dm = - \overset{\text{rev.}}{0{\cdot}0062}$$

The divergence between the first series and the second, due to this cause, would therefore be that produced by a difference of $\overset{\text{rev.}}{0{\cdot}0106}$ in the micrometer readings. Now the mean value of the displacement due to rotation, for latitudes less than 30°, was $\overset{\text{rev.}}{0{\cdot}099}$; for latitudes between 30° and 75°, was $\overset{\text{rev.}}{0{\cdot}060}$. So that the heating effect would explain for lower latitudes a divergence of 11 per cent, and for higher latitudes, a difference of 18 per cent between the results of the first and second series. It is thus fully competent, on the assumptions we have made, to explain the discrepancy between a velocity of 2·565 mi. per sec., obtained in the first series, and 2·173 mi. per sec., obtained in the second.

Dividing this error in the ratio $\frac{0{\cdot}0044}{0{\cdot}0062}$, we have for a final value

$$v' - v'' = 2{\cdot}403 \pm 0{\cdot}026 \text{ mi. per sec.,}$$

which corresponds to a sidereal period of 26·23 days, or a daily angular motion of 824′.

It is to be observed that this result is independent of any assumption as to *how much* the slit is heated. The divergence between the two series has simply been divided in the ratio of $\frac{\cos i}{\cos r}$ for the position "right" to $\frac{\cos i}{\cos r}$ for the position "left."

To determine the change of angular velocity with latitude, I have drawn through the observations of the *second* series the straight line which most nearly represents them, and find by the method of least squares its equation to be:

$$\theta = 802'(1 - 0{\cdot}00206\, \chi^\circ)$$

where θ is the daily angular motion, and χ the heliocentric latitude, expressed in degrees. This would indicate acceleration as we approach the equator. The *first* series gave:

$$\theta = 838'\,(1 + 0{\cdot}00335\, \chi^\circ).$$

Since the error due to heating affects the higher latitudes more than the lower, in the ratio of the secants of the latitudes; and since it enters the two series with opposite signs, the coefficients of χ, in any accurate work, *ought* to have opposite signs, always provided there was in reality no very marked change of angular velocity with latitude.

Combining these two expressions:

$$\theta = 823' (1 + 0{\cdot}00065\, \chi^{\circ}).$$

The co-efficient of χ is too small to put much stress upon, when we consider the necessarily large errors in the observations from which it was derived. As it stands, however, it indicates that points in latitude 45° rotate in 18 hours *less* time than points at the equator, while Carrington's expression for sun spots,

$$\theta = 865' (1 - 0{\cdot}191, \sin^{\frac{7}{4}} \chi^{\circ})$$

would make the rotation period at 45° some 2½ days *longer* than at the equator. The difference between the two is quite marked. Can it indicate that the spectroscope measures the velocity of regions, corresponding in some degree to upper or lower "trades," the angular velocity of each of which would *decrease* from the equator to poles?

But it is not easy to think of any cause competent to produce "trades" on the sun, since no certain difference of temperature* between equator and pole has ever been discovered. The evidence afforded by these observations, therefore, is, that *no certain variation of period with latitude has been detected by the spectroscope.*

Wilsing (l. c., p. 436) has examined the motion of faculæ with reference to this same phenomenon, but failed to find any "drift" or change of velocity with latitude.

The following table may, I think, be considered as fairly representing the best determinations of the *sidereal* period of points on the equator.

From Barometer and Thermometer.	*Hornstein*—from daily range of barometer at Prague during the year 1870,	24·12
	Braun—from daily average of barometer at Singapore, 1841–1845,	24·13
	Van der Stok†—from daily average of barometer,	24·10
	" " range " "	24·11
	" " average " thermometer,	24·10
	" " range " "	24·14
	Von Betzold‡—from thunderstorms in Bavaria and Wurtemberg,	24·12

* Young's *Sun*, p. 264.

† Van der Stok: Natuurkundig Tijdschrift voor Nederlandsche-Indie, Deel 48. The observations extend over 7740 days, were made in the tropics where the amplitude is large, and are entitled to great weight.

‡ *Nature*, April 11th, 1889.

Variation of Magnetic Elements.	*Hornstein*—variation of magnetic elements at Prague and St. Petersburg during 1870,	24·51
	Braun—variation of magnetic elements at Greenwich and Makerstown during five years, between 1844 and 1870,	24·18
	Liznar—magnetic disturbances (storms),	24·29
Photosphere Equatorial values.	*Carrington*—from sun spots—seven years' observations,	24·97
	Sporer— " " "	24·60
	Wilsing—from faculæ,	25·23
	Crew—by spectroscope, equatorial value,	26·23

It will be observed that the lowest value by any one method is higher than the highest of the next preceding. May this not correspond to a physical fact, viz: that as we pass from the more central portions of the sun, up through the photosphere, faculæ, and absorptive layer, there is a gradual decrease of angular velocity?

Haverford College, April 16, 1889.

Art. XXVIII.—*The "Grand-Gulf" Formation of the Gulf States;* by Lawrence C. Johnson.

The group of clays, sands, sandstones and quartzites called the Grand-Gulf formation by Dr. Eugene W. Hilgard, has a boundary as yet undefined in Texas and Louisiana, and is little better known in the States east of the Mississippi River. Dr. Hilgard considers it of fresh water origin, and upon good grounds; but of what precise age no one has been bold enough to advance a definite opinion. Fossils are rare: a few *Uniones* have been found, and in places, there are many leaf impressions. It cannot be older than *Miocene*, and is as certainly not Quaternary.

The sandy clays, and quartzose sandstones of this formation are so peculiar in structure, colors and general appearance that they are easily recognizable, and cannot well be mistaken for any other in these States, much less for any of the calcareous groups northward of it. By all observers it is agreed that the strata next in this direction, are of Dr. Hilgard's Vicksburg Formation. The trend of the northern boundary of the "Grand Gulf"—from the vicinity of the place giving it its name, in Claiborne County, Miss., is southeastward at such an angle that at the Alabama line it has a breadth only half as great as on the Mississippi River, that is: allowing an average of twenty miles for the coast formations, it is about sixty miles in width next to Alabama, against one hundred and twenty-five on the meridian of Vicksburg. No critical surveys of it having been made and its eastern extension is only conjectural.

Adjoining the Great River, the "Grand Gulf" formation is covered first by the sands and gravels called by Dr. Hilgard "the Orange Sand;" and this is overlain by his "Port Hudson" and lœss. At a dip, estimated as between twenty and thirty feet to the mile, the average thickness must approximate two hundred feet.

Though a geological examination of this obscure portion of our Gulf terranes has only commenced, the relation of the "Grand Gulf" to the underlying and overlying formations, having within the last three or four years been called in question, some recent observations on the line of the calcareous Eocene outcroppings may be of general interest.

As already intimated, there is no dispute as to later strata. The so-called "Orange-Sand," at least to the west, covers the "Grand Gulf" to unequal depths. Many sections in Claiborne, Jefferson and Adams Counties, Miss., on the smaller tributaries of the Mississippi, exhibit the great gravel beds assigned by Dr. Hilgard to his "Orange Sand," resting upon it, as the lœss there rests upon the gravel. Underlying it, we are not so fortunate as to possess many satisfactory exposures. The relations here were rather an inference on the part of Dr. Hilgard, founded upon general principles, and not from instances of actual visible contact. It has even been said that no locality shows exactly the relative position of the two, so as to prove conclusively Dr. Hilgard's hypothesis. Mr. Otto Meyer thought he saw a contact of these in a cut of the Vicksburg and Meridian Railway, near Pelahatchie, Miss., and he regarded it as proof of his hypothesis that the "Grand Gulf" is the older, and that the superposition is the other way.

Having traced the course of the Eocene rocks across several counties of Mississippi, and seen the exposures on almost all of these small rivers and railroad cuts, I have no doubt whatever of the correctness of Dr. Hilgard's views. Had no locality of actual contact been found, the evidence would still be satisfactory, for in every instance in this State, and in Alabama, and in Louisiana, where the stratification could be observed of either of these formations, the dip has been found uniformly southward.

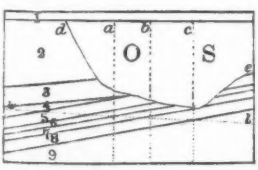
To set all questions aside, at least one point of actual contact has been found. As a general rule, the streams of this region run southward, and cut across the structure of the formations, but they fail to make many bluffs, and these not at points to expose the strata and their relative positions. On Chickasawkay River, however, the bluffs, which extend in almost unbroken series for more than twelve miles between Shubuta and Winchester, display every layer from the former in the middle of the Jackson formation to Brown's Bend in

Wayne County, three miles southeast of Waynesboro, where the Grand Gulf stands alone, with clean cuts of its peculiar clays and quartzitic rocks, to a thickness of seventy feet. The most southern three miles of these exposures are particularly instructive.

Beneath the surface actually visible at Brown's Bend lie two beds of clay, very sandy, very compact, and of a greenish-yellowish color, mottled with pink, on the whole of a cast seen only in the Grand Gulf formation, and indescribable. They are six to eight feet in thickness each, and have a layer of sand, one foot deep, intercalated between them. Beneath this double bed of clay, lies another layer of sandy material, about two feet thick, containing lumps and fragments possibly of organic origin but not recognizable. This much, unseen at the Bend itself, crops out half a mile farther north; and still a little farther, all these layers, the double-bedded clay and attendant sands, appear above water at a low stage, with sufficient of the underlying strata fully to explain the nature of the unstratified sand beneath the clays.

The first that comes to the surface beneath the above described clays and sands, is about four feet thick, and a very compact sand made up as it were of fucoidal stems like tangled roots. Beneath this lie four to six feet of a dark crumbling sand filled with spines and fragments of Echinoderms and decayed remains of Ostrea. One mile up the river from Brown's Bend, at Trigg's Old Ferry, all these fossiliferous layers may be seen well above water, together with the next underlying, which at this point consists almost exclusively of gigantic oyster shells. At Cochran's Ferry, a few hundred yards still farther north, ten feet of this great Ostrea bed are visible at low water, and other Vicksburg fossils are discoverable scantily among the oyster shells.

A general section may be made to show the structure from Brown's Bend to Cochran's Ferry, one and a half miles, as follows:



OS. Stratified Orange Sand; 1, sandy soil with pine woods, old terrace, 10 ft. thick; 2, gray sandy clay, 60 feet; 3, compact whitish sand, becoming sandstone in places, 20 ft.; 4, clays, 10 feet; 5, clayey sands, no distinct fossils, 6 feet; 6, fucoidal hard sands, 2 feet; 7, compact sands, with fragments of *Ostrea* and other shells, 3 feet; 8, dark sands, with fragments of Echinoderms, 5 feet; 9, bed of *Ostrea gigantea* and *O. Vicksburgensis*, etc., over 10 feet of it, probably 30 to 40 feet; two miles to the north this mingles with the Vicksburg limestone of Huggins Bluff having *Orbitoides Mantelli* and *Pecten Poulsoni*; *a*, line of calcareous Eocene; *b*, Trigg's Old Ferry; *c*, Cochran's Ferry; *d* to *e*, line of very old erosion filled in again with the so-called Orange Sand; *w l*, water line.

At Trigg's Old Ferry, by means of a small spring branch, which comes pouring out of the sands a short distance to the

west, everything has been washed away and again covered, so as to alter and hide the original bluff down to the compact fucoidal sands, which a full stage of water would protect and conceal. And at the other point mentioned where the fossiliferous layers are first seen beneath double-bedded joint clays, quite a bold spring branch comes in with like effect; for it has cut through all the layers down to low water and by stealing out in preference the soft, sandy layers, has so let down and distorted the lay of the clays, that it is difficult to determine the dip. On occasion of the first visit the writer supposed it to be the same as that of the calcareous beds. Upon further observation, he is satisfied that it is less. That is: putting the dip of the Vicksburg rocks at thirty feet to the mile—and it cannot be less—the Grand Gulf is probably about twenty feet and can scarcely be more. To settle this exactly will require further and more careful observation.

This layer of the Vicksburg formation, in which the great oysters abound, may be followed up the river more than two miles, and cannot be much less than forty feet in thickness. Echinoderms and corals become more common in the lower portions of it, and with them, among other things, are conspicuous the great tubes of *Aspergillum* or some kindred *Tubicola*—all forming a transition of Rotten limestone, before passing to the hard bluffs of *Orbitoides* rocks, constituting so much of the river bed for the next six miles.

All the eastern bank of the river is made of a kind of second-bottom, from one to three miles in width, having a few low places through which the river runs at high water, and many sandy knolls over which the water never rises. In some of these branches, and in all the wells dug in this flat, the Rotten marl, having shells of *Ostrea Vicksburgensis*, is found near the surface. Along the foot of the hills eastward there are sand hills and benches, evidently remnants of an olden terrace.

The older terrace constitutes wholly the western bank of the river and its towering bluffs. At Cochran's Ferry the bluff cannot be less than one hundred feet high, and consists entirely of soft sands, resembling "Orange Sand." Though so near the terrace of compact clays at Brown's Bend, these sands at Cochran's have not the faintest resemblance to the Grand Gulf strata of the hills to the west and south. Evidently there has been a great erosion, and refilling at this point and for some miles farther north; all which may be gathered from the section herewith exhibited.

These notes are offered, not with a view to controversy, or to re-open a discussion: It can hardly be said, that there is a serious doubt in the premises, but as a statement of facts, and an attempted description of a locality in itself interesting, and worthy of a visit.

Art. XXIX.—*Radiant Energy and Electrical Energy;* by John Trowbridge.

The relations between radiant energy and electrical energy are daily becoming more important, and the experiments of Hertz on Electrical Rays lead one to ask whether the doctrine of the conservation of energy can guide us in answer to the question, what are the transformations of energy in a dielectric submitted to rapidly alternating electrical stress?

Hertz has also shown that ultra violet waves of light exercise a marked influence upon the striking distance of the electric spark. E. Wiedemann attributes this effect to a selective absorption of the metals between which the spark is passed. Thus platinum terminals show the effect in a more marked degree than the terminals of other metals, and it is well known that platinum exercises a marked selective absorption for violet rays. This explanation of the phenomenon observed by Hertz may however be only a partial explanation. The question still remains, do ultra violet rays exert any effect upon a dielectric which becomes manifest in changes of electrical stress? Or, to put the question in another form, are the shorter waves of electrical energy passing between the plates of a condenser, separated by various dielectrics, absorbed by the dielectric, or is this the case for the long waves only? It is well known that a dielectric is under stress when submitted to rapidly alternating electrical charges. Under the supposition that an electrical wave or disturbance in the ether carries heat and light waves; or that there is a close correspondence between the phenomena of light and heat waves and electrical waves, we are led to ask if there are not transformations similar to those Alexander Graham Bell has shown to exist in substances submitted to the action of rapidly interrupted waves of energy in the form of heat. The Radiophone shows that the long waves of energy become absorbed in passing through various substances. The transformation of energy is shown by a musical note which is that of the wheel employed to interrupt the beam of light which falls upon the substance under examination. The effect is evidently due to the long waves of energy which we call heat. The effect might have been anticipated; for Balfour Stewart had shown that a body subjected to changes of temperature undergoes a change not only at its surfaces, but also throughout its interior. The rapidity of these changes, however, had not been suspected until the invention of the Radiophone.

In the case of the Dolbear telephone, electrical oscillations are transmitted from one plate of an air-condenser to another.

With this instrument we have no guide or indication of the size of the electrical undulations which are transformed while creating a stress in the dielectric which separates the two plates of the condenser. I was led, therefore, to examine the specific inductive capacity of well known insulators in order to perceive if any relation exists between such inductive capacities and the selective absorption of radiant energy which these substances may exhibit. The first substance selected was naturally paraffine. In order to examine its selective absorption a layer of it in the melted condition was contained between quartz plates. In order to keep it melted the plates were imbedded in sand, an aperture being left for the passage of light, and placed over a Bunsen burner. Light passing through the paraffine was then examined by means of a spectroscope provided with quartz lenses and a quartz prism. It was found that the paraffine transmitted the ultra violet rays certainly as far as wave-length 3400. There was evidence that absorption of the ultra violet rays began in the neighborhood of this wave-length. Thin sheets of vulcanite were next examined. These transmitted light through the extent of the visible spectrum from the extreme limit of the red to the beginning of the blue region of the solar spectrum. It was opaque to the blue and the violet.

The following table gives a comparison of the specific inductive capacities of the substances examined and the range of their selective absorption in the ultra violet.

Dielecric.	Specific inductive cap.	Limit of transmission.
Glass	3·243	about 3800
Paraffine	2·32	about 3400
Ebonite	3.15	opaque
India rubber	3·24	opaque
Quartz	4·6	below 2000
Iceland spar	8·4	below 2000

Boys has lately called attention to the remarkable insulating qualities of quartz.

From the above table we are apparently justified in drawing the conclusion that the long waves of electrical radiation, the existence of which has been shown by Hertz, behave like the long waves of radiant energy which we term heat waves, and perform work in the dielectric when transmitted in an alternating manner through it. The short waves of electrical energy if they are analogous to the short waves of light are apparently not absorbed by the dielectric when this dielectric approaches perfection as a dielectric. The theory, therefore, that electrical attraction may be due to extremely rapid vibrations of the ether which cause attraction of bodies, much as a pith ball is

attracted to a vibrating prong of a tuning fork, is apparently not supported by the new theory that very short electrical wave-lengths are closely related to very short wave-lengths of light: for we should expect that there would be an absorption of these extremely quick oscillations of light or electricity when the attraction between the conductors, insulated by a dielectric, increases. Calling K the specific inductive capacity of the medium between two plane conductors, S the area of the opposed surfaces, c the distance between the plates B and A the potentials of the plates, we have total energy $Q=\frac{KS}{8\pi c}(B-A)^2$. This evidently increases with the value K.

The relations between electric conductivity and opacity have been discussed by Maxwell, vol. ii, p. 798. Calling V the velocity of propagation, K the resistance in electromagnetic measure, of a plate whose length is l, breadth b and thickness z. The proportion of the incident light which will be transmitted by this plate will be of the form

$$\varepsilon \quad \frac{-4\pi\mu l V}{b R}$$

This proportion evidently increases with the value R.

Jefferson Physical Laboratory.

ART. XXX.—*Note on the fossil Spider Arthrolycosa antiqua* Harger; by CHARLES E. BEECHER.

IN the March number of this Journal for 1874, Mr. O. Harger described and illustrated a fossil spider from the lower Coal Measures of Illinois,* under the new generic and specific designation of *Arthrolycosa antiqua*.

While examining the type specimen in connection with preparing a series of fossils to illustrate Dana's Manual of Geology, it became evident to the writer that all the features of the fossil had not been observed at the time of the original publication. The specimen was then studied and figured in the condition in which it was first discovered, and had never been sufficiently cleaned, nor had the appendages been exposed by removing the superincumbent matrix. This has now been accomplished, and results render it necessary to make some modifications and additions to the original description, as well as to give an illustration of the specimen in its present state. These changes are quite important as *Arthrolycosa* is one of

* Notice of a new Fossil Spider from the Coal Measures of Illinois, viii. 219–223.

the oldest of the spiders, and the original figure has been copied into text books and general works on Paleontology.

A re-examination of the type was make by Professor Samuel H. Scudder in 1884,* and the only change from the original description suggested by him was in the character of the appendages then considered as the palpi. The conclusions reached were the following (*loc. cit.*): "Having reason, by its undoubted relationship to other forms of Anthracomarti, to doubt the forcipulate character of the palpus, . . I find on close examination that not only is the joint in question not chelate, but it terminates by a straight transverse suture, and is followed by a portion of another, apparently short terminal joint."

The specimen now shows that these members are not the palpi, but are the anterior pair of legs. The true palpi have been exposed, and the full number of cephalothoracic appendages revealed, including the normal number of eight legs, the palpi, and the mandibles.

Figure 1 represents the specimen as it now is, and the original illustration, figure 3, is introduced for comparison.

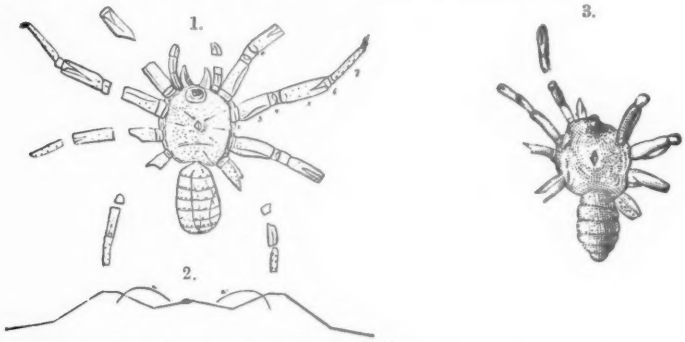


Figure 1.—Dorsal aspect of type; natural size.
Figure 2.—Profile showing elevation of cephalothorax and position of legs. *a*, *a*,' profile of palpi.
Figure 3.—Original illustration.

The cephalothorax is subcircular in outline, with a slight sinus in the posterior margin for the insertion of the abdomen. It measures about 10^{mm} in diameter. The surface gradually rises toward the center, which is occupied by a deep rhomboidal pit marking the point of attachment for the muscle moving the sucking stomach. From this point, radiating grooves extend to the margin, indicating the ventral coxal

* Proceedings of the American Academy of Arts and Sciences, 1884. A contribution to our Knowledge of Paleozoic Arachnida, p. 15.

elements, and near the center of the posterior half, there is a sharp transverse ridge extending about two-thirds across the body. The anterior border presents a conical elevation measuring 3^{mm} in transverse diameter, and showing on its summit two oval prominences in which the ocelli were undoubtedly located. Two of them seem to be distinctly marked and are represented in the figure, while the others are obscurely shown and are not delineated.

Both mandibles are well preserved, and consist apparently of a short basal joint and a strong arched angular grooved terminal portion. Their position and character seem to indicate that they were moved vertically as in the Territelariæ (*Avicularia* = *Mygale*), and not laterally as in the majority of spiders. They project 3^{mm} beyond the margin of the carapace, and extend downward a distance of at least 1·5^{mm}.

The palpi are shorter and more slender than the legs, and to all appearances simply terminated, except that the inner edge of the extremity is marked by a small excavate area which may indicate the male palpal organs. Three or four joints can be made out, each being marked by a longitudinal ridge. Entire length observed, 6^{mm}.

The four pairs of ambulatory appendages differ little in character and can be homologized, joint for joint, with the Tetrapneumones. The two anterior pairs are somewhat more robust than the others, but present the same general features. Beginning with the distal joint as preserved on the second pair of legs, it is found to measure 6^{mm} in length and is elongate and slender in form, ending in some obscurely defined bristles and claws. The surface is strongly marked by pitted pustules, probably indicating the bases of the stronger hairs. The next, or sixth joint, is short, not longer than wide, and without ornament. The fifth segment is stout, measuring 7^{mm} in length and 2^{mm} in width, and furnished on its distal half with a triangular groove extending to the anterior articular face; surface with a few scattered capillary pits. The fourth and second segments are short and robust, resembling the sixth, while the third is similar to the fifth, but shorter and furnished with a flattened margin instead of a triangular groove. As the specimen presents only the dorsal aspect, the coxal elements of the limbs cannot be described.

The abdomen is as long as the cephalothorax, but only a little more than half the width of that portion. It is ovoid in form, very much constricted anteriorly where it joins the cephalothorax, and gradually widens posteriorly to the fifth segment. The specimen preserves seven segments which gradually decrease in length from the first to the seventh. Each is ornamented with a single row of nodes on its posterior border,

and in addition, the last somite shows a depressed central area which may correspond to the spinneret, but otherwise, no abdominal appendages can be detected. The longitudinal lines represented in the figure have been produced by the folding of the test, due to compression in the rock.

Considerable interest is attached to the position and association of the specimen. From the figure and profile, it is seen that all the elements of the spider are in nearly their natural position, having undergone but slight distortion, while its perfection indicates that it is not a shed skin which is preserved, but that the actual animal was entombed.

In the same concretion are fragments of the broad leaves of a rush-like plant, and it is not improbable that they furnished a float upon which the spider was carried out from the land so that its remains are found mingled in the same beds with marine organisms.

With the additional evidence furnished by the original specimen, the systematic position of this form is open to revision.

It has been generally recognized as the type of a new family, Arthrolycosidæ, as first established by Mr. Harger. Professor Scudder placed this family at the beginning of the order Anthracomarti. The characters of the order as enumerated by him are: "Body somewhat depressed, the cephalothorax and abdomen distinctly separable. Cephalothorax usually made up in large part of more or less wedge-shaped pedigerous segments, the arrangement of which corresponds to that of the coxæ. Abdomen forming a single mass and composed of from four to nine distinct joints. Palpi not much longer than the legs and simply terminated."*

With the exception of *Arthrolycosa*, all the families of this order comprise species which have the abdomen larger than the cephalothorax, and divided longitudinally into well defined areas. The cephalothorax is composed of distinct wedge-shaped pedigerous segments, while in *Arthrolycosa*, it is formed of a single piece, not more divided into coxal elements than in the living species of Tetrapneumones.

The palpi of the Anthracomarti are said to be "not much longer than the legs," and, in this respect, *Arthrolycosa* differs in having short stout palpi, about twice as long as the mandibles, and reaching to the fourth segment of the anterior legs. The arrangement of the eyes and mandibles is also quite distinct in the two groups.

On account of these important differences, it seems necessary to exclude the genus from the order Anthracomarti, and at present, a strict interpretation of any of the orders will not admit this form.

*Bulletin U. S. Geol. Surv. No. 31, Systematic review of our present knowledge of fossil insects, including Myriapods and Arachnids. Washington, 1886.

The marked resemblance between the recent *Avicularia* (*Mygale*) and the fossil appears to be grounded upon more than trivial characters. *Avicularia* and allied forms, constituting the Tetrapneumones, with four air sacs in the abdomen as among the Scorpions, eight ocelli, two pairs of spinnerets, and vertically acting mandibles, form a division of the Araneina of much greater significance than a family, and this fact has been recognized in the separation of the order into the Tetrapneumones and Dipneumones. The first division embraces the suborder Territelariæ including the families Theraphosidæ and Atypidae, (Tarantulas and large hairy spiders), and the second is divided into six suborders and thirteen families, to which belong all the true spiders.

The similarity of organs used for sight, locomotion, and procuring food, is of much greater importance than the external segmented or unsegmented nature of the abdomen, which structurally and primarily is truly segmented, as shown by the anatomy, embryology and phyllogenetic history. Taking this view, it is seen that a slight extension of the characters generally ascribed to the Araneina, in the single direction of the segmented nature of the abdomen, will admit *Arthrolycosa* and place it in the division Tetrapneumones. From present information, there seems to be no marked characters which would exclude it from forming a family in the suborder Territelariæ.

Mr. J. H. Emerton previously called the attention of Mr. Harger to the general affinities between *Arthrolycosa* and *Mygale* (*Avicularia*) as noted at the end of the original description. At that time, however, the apparent forcipulate character of what was termed a palpus outweighed all other considerations.

Yale University Museum, June, 1889.

ART. XXXI.—*On the Parayenesis of Allanite and Epidote as Rock-forming Minerals;* by WM. H. HOBBS, Ph.D.

THE interesting discovery of Messrs. Cross and Iddings,* of the U. S. Geological Survey, that the mineral allanite or orthite occurs widely distributed as a constituent of many varieties of rocks, has placed this mineral in the list of important accessory rock-constituents, and called the attention of American geologists to its distinguishing characters. In Europe, allanite, or orthite, which is the term commonly used in Germany for the same mineral, had already become recognized as one of the rarer constituents of a few rock species. As early as 1860, K.

* Cross and Iddings, Wide-spread Occurrence of Allanite as an accessory constituent of many Rocks, this Journal, III, xxxii, p. 108, Aug., 1885.

von Fritsch* described this mineral in the granitite of Ilmenau in the Thuringian Forest. Vom Rath† recognized it as an important accessory constituent of the tonalite of Mt. Adamello. Interesting occurrences are mentioned by Liebisch‡ in the granite porphyry of Erdmannsdorf and other localities in Lower Silesia, and by Törnebohm§ in an amphibole-biotite granite from Eastern Siberia. Our knowledge of the optical properties of allanite has been much advanced by the investigation of this mineral in the granite of Pont Paul near Morlaix, Finisterre.‖

The occurrence of allanite and epidote as constituents of the same rock has been several times observed, and by two investigators these minerals have been found so intergrown, as to add evidence of isomorphous character to that already known to exist in the similar crystal form and analogous chemical composition.

In 1854, Blomstrand¶ described from Wexio in Sweden crystals of pistazite arranged radially about cores of allanite; and somewhat later Ewald Becker** mentioned inclusions of orthite in the epidote of a granite from Striegau. Messrs. Cross and Iddings†† observed apparent inclusions of epidote in allanite. It is further stated in many text-books‡‡ that cores of allanite in epidote and cores of epidote in allanite, occur at Sillböhle in Finland. After some search I am unable to designate the original paper by Nordenskiöld, but through the courtesy of Professor Wiik of Helsingfors, I have a copy of the catalogue to the mineral collection of the Helsingfors University§§ in which the interesting intergrowths are figured. A similar intergrowth has been recently found by Törnebohm‖‖ to characterize the epidote-gneiss of a considerable portion of Wermland. "Small crystals which have been taken for orthite and which are crystallographically similar and oriented like their host, occur in the epidote."¶¶

* Geognostische Skizze der Umgegend von Ilmenau im Thüringer Walde. Zeitsch. d. d. Geol. Ges., xii, 105.

† Beiträge zur Kenntniss der eruptiven Gesteine der Alpen, I, ibidem, xvi, 255, 1864.

‡ Ueber die Granitporphyre Niederschlesiens, ibid., xxix, 725, 1877.

§ Vega Expedition IV, 115–140, Stockholm, 1884. Ref. Neues Jahrb. f. Min., etc., 1885, i, 429.

‖ Michel Lévy et Lacroix. Note sur un gisement français d'allanite, Bull. soc. minèr. de France, xi, No. 2, 64, Feb., 1888.

¶ Blomstrand, Oefvers. af akad. Förhandl., 1854, No. 9, p. 296. Ref. Journ. f. prakt. Chem., lxvi, 156.

** Ewald Becker, Ueber das Mineralvorkommen im Granit von Striegau insbesondere über den Orthoklas und dunkelgrünen Epidot, Breslau.

†† Loc. cit.

‡‡ Dana, Brooke and Miller, etc.

§§ F. J. Wiik, 1887, p. 27, pl. II, fig. 7.

‖‖ Törnebohm. Mikroskopiska bergartsstudier, XIII Epidotgneiss. Geol. För. i Stockholm Förhandl., 1882, No. 75, vi, 189.

¶¶ Ref. Cohen, Neues Jahrb. f. Min., etc., 1883, i, 245.

While engaged in the study of the geology of a section of the Johns Hopkins University map, two epidotic minerals were found to play an interesting rôle as accessory constituents of the porphyritic granite of Ilchester. A short notice on the geological relations of the rocks of this area, together with mention of parallel growths of epidote and allanite, appeared in April, 1888.* After a further examination of these interesting intergrowths, it is my purpose in the present paper to consider them more fully in connection with what has already been said concerning epidote and allanite.

The Ilchester granite, in which they occur, is one of the youngest of a series of eruptions in the gneiss and crystalline schist of eastern Maryland. It is a medium to coarse-grained rock, with a porphyritic aspect caused by the large microcline crystals scattered through the holo-crystalline to granophyric ground-mass. This ground-mass contains as essential constituents, varying proportions of monoclinic and triclinic feldspar, and biotite. By the more or less complete replacement of biotite by hornblende, the granitite develops facies of hornblende granite. Besides allanite and epidote the only important accessory constituent is a colorless mica. Throughout the entire area of the section studied, the granite shows evidence of "stretching" in its more or less perfect "parallel structure," and in the broken character and disturbed optical properties of the constituent minerals.

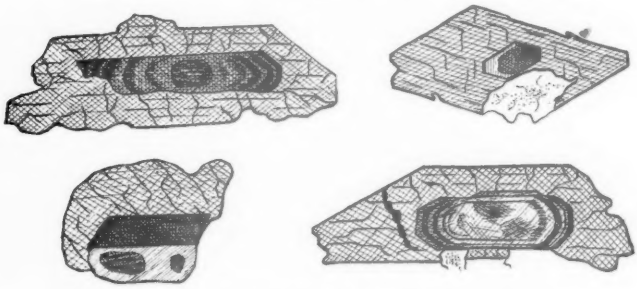
The epidote is macroscopically visible in the rock, generally as yellow columnar crystals one to three millimeters in length, though it is often without crystalline form. A brownish kernel is frequently visible within the epidote, and when prismatic planes are developed upon the latter, the perfect parallelism of the corresponding faces of the two minerals can be observed. The junction of the included mineral with its host appears as a sharp line, owing to the difference in color of the two minerals. The included mineral shows no distinct cleavage, is very brittle, and is found in some specimens of the granite decomposed to a brown powder. The brittle character of this mineral has prevented its removal from the matrix and examination with the goniometer.

Under the microscope its isomorphous relation to epidote is strikingly shown in many instances by the parallelism of the bounding planes of the two minerals and its distinct character

* Wm. H. Hobbs, On the rocks occurring in the neighborhood of Ilchester, Howard County, Maryland; being the detailed study of the area comprised in sheet No. 16 of the Johns Hopkins University map. Johns Hopkins University Circulars No. 65. (Preliminary notice of a dissertation for the degree of Doctor of Philosophy).

marked by a beautiful zonal structure absent in the epidote. The forms observed were M (001), r ($\bar{1}01$), T (100), and somewhat imperfect terminal planes, the symbols of which could not be determined. When not too deeply colored the long

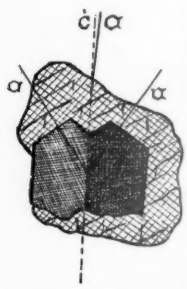
1.



Sections of intergrowths in the Ilchester granite, × 50.

sections yield an optic axis, which shows the plane of the axes to be the clino-pinacoid (010). Such sections therefore extinguish the light parallel and perpendicular to the long axis (b). The index of refraction is strong, while the double refraction is feeble, the interference colors between crossed nicols being of the first order, even when the slides are above the usual thickness. The dispersion is very strong, making indistinct the extinctions in polarized light. Twins parallel to the ortho-pinacoid were rarely observed. A chance section of such a twin appears in fig. 2. The symmetry of extinction with reference to the composition seam and the form of the section, are evidence that the plane of the section, lies nearly or quite perpendicular to the axis b. In either individual the axis of maximum elasticity makes an angle of 36° with the vertical axis, but in the absence of cleavage and perfect planes, it was impossible to determine whether this axis of elasticity lies in the obtuse or in the acute angle β. The surrounding epidote is allotriomorphic and a single individual, but orientated like one of the included crystals, as is shown by its axis of maximum elasticity, which makes an angle of 3° with the twinning plane of the inclusion. The pleochroism of the included mineral is one of its most marked characters, and has been determined to be as follows: a light yellowish-brown, b chestnut-brown, and c dark greenish-brown. The absorption is like epidote $c > b > a$.

2.



Section of twinned allanite crystal with mantle of epidote, × 5.

These characters belong to the mineral allanite and a comparison shows that they are the same as are possessed by the allanite of the Ten Mile Region of Colorado.* Further comparison with slides from the epidote-gneiss of Wermland in Professor Rosenbusch's collection shows that in this case, as in the Ilchester granite, we have to do with parallel intergrowths of allanite in epidote.

Since publishing my first notice of these intergrowths, the suggestion has been made that the surrounding mineral may not be epidote, but that it may be allanite whose color and optical differences are to be accounted for by slight differences of chemical composition; in other words that we have to do with a case of zonal structure in allanite. The characters of the epidote require therefore careful consideration.

The examination in thin section under the microscope shows the epidote to possess, in the majority of cases, the prismatic planes, M, *r*, and T. The longer sections of these crystals exhibit cleavage lines parallel to the longer axis, and yield in converging polarized light an optic axis, which often appears on the edge of the field. The plane of the optic axes is perpendicular to the ortho-diagonal and the optical angle is large. The cross-sections of crystals show an imperfect cleavage parallel to M (001), and a poor cleavage parallel to T (100). The cleavage angle measured 115°. The angle of maximum elasticity lies in the acute angle β and makes with the vertical axis an angle of 3° to 3° 3′. The pleochroism is distinct and as follows: a nearly colorless, b light straw-yellow, c siskin-green The absorption is written $c > b > a$.

By the use of the Thoulet solution a quantity of epidote together with some admixed allanite and titanite was separated from the rock, and ·45 gram obtained pure by the tedious process of picking out the fragments of allanite and titanite, their darker brown color serving to distinguish them. I am indebted to the U. S. Geological Survey for an analysis of this powder by Dr. W. F. Hillebrand. Special examination was made to determine the presence or absence of the rare earths, but no trace of any was discovered. The material used in this examination necessitated a determination of the alumina by difference. The amount of ferrous oxide was not determined. The water was determined by loss on glowing. The results of Dr. Hillebrand's analysis are given under I. An analysis of the Untersulzbach epidote by Ludwig is introduced under II by way of comparison.

* The sections of the biotite-porphyrite of this region were kindly loaned me by Dr. Cross of the U. S. Geol. Survey.

	I.	II.
SiO_2	37·63	37·83
Al_2O_3	[20·86] difference	22·63
Fe_2O_3	15·29	15·02
FeO		0·93
MnO	0·31	----
CaO	22·93	23·27
MgO	0·31	----
H_2O	2·23	2·05
P_2O_5	0·44	----
	100·00	101·73

If we consider the phosphoric oxide as due to inclusions of apatite, and disregard the traces of manganese and magnesia, the analysis corresponds very closely with the formula $2H_2Ca_4Al_6Si_6O_{26}+H_2Ca_4Fe_6Si_6O_{26}$.

The peculiar intergrowths that have been described are characteristic of the Ilchester granite throughout the twenty-five square miles of the section studied.* Colorless inclusions, probably apatite, as well as biotite, are occasionally found in the allanite. With little doubt, the latter is one of the earliest separations from the magma. The origin of the epidote is not so easily settled, but the "stretched" character of the granite is in favor of a metamorphic origin through pressure. Against such a view is the discovery by Professor Williams that the Woodstock granite, which is particularly rich in these intergrowths, shows no evidence of cataclastic action.

In conclusion I would gratefully acknowledge obligation to my much honored teachers, Professor Williams of the Johns Hopkins University in Baltimore, and Professor H. Rosenbusch of Heidelberg, Germany.

After the foregoing article left my hands, there was brought to my notice the recent important paper of Lacroix on Pyroxene-gneiss and Wernerite Rocks (Contributions à l'étude des gneiss à pyroxène et des roches à wernerite, Bull. de la Soc. française de Minéralogie, tome xii, No. 4, April, 1889). The author describes similar epidote-allanite intergrowths in the pyroxene-amphibole gneiss of Finisterre (pp. 138–9, fig. 21); in the pyroxene-wernerite gneiss of the Lower Austrian Waldviertel (p. 157, pl. I, fig. 5); and in the wernerite gneiss of Odegården in Norway (p. 210). M. Lacroix has found the same properties to characterize the allanite and epidote of these localities as have been determined for the Ilchester intergrowths, specimens of which he has used for comparison. He considers the epidote primary in all the occurrences described by him (p. 353).

* I am informed by Prof. Williams that he has found such epidote-allanite intergrowths to be characteristic of the surrounding Ellicot City and Woodstock granites, but wanting in the Guilford granite which occurs farther to the south.

Art. XXXII.—*A new locality of the Camptonite of Hawes and Rosenbusch;* by Frank L. Nason.

In Hitchcock's "Geology of New Hampshire," Part IV, "Mineralogy and Lithology;" also in this Journal, vol. cxvii, p. 147, Dr. G. W. Hawes describes a "group of dissimilar eruptive rocks in Campton, N. H." Dr. Hawes calls these dikes respectively, diabase, olivine diabase, diorite and syenite. There are five dikes in all: one each, of the first three and two of the syenite. One of these dikes which Dr. Hawes has called a diorite, Professor Rosenbusch, in his last edition of the "Mikroskopische Physiographie der Massigen Gesteine," p. 333, has called Camptonite after the locality where it was first observed.

In the summer of 1885, the writer, while crossing the Green Mountains along the line of the Rutland and Burlington R. R. between Rutland and Bellows Falls, Vt., encountered a peculiar rock in a cut near the station called Summit. This rock was observed to occur in the form of a dike cutting across the quartzite and the gneisses of the Green Mountains. The dike, however, had a N. W. dip, strike N. E., S. W., while the country rocks dipped S. E. The dike is about six feet in width. Near its outer boundaries the contact with the rocks through which it broke prevented the coarse crystallization which took place in the center. It does not appear on the surface or either side of the cut. Careful search was made for it but without success. The reason is assumed to be that the dike rock is much more susceptible to weathering than the country rock. The hope of tracing the dike to some central chimney or throat was thus abandoned.

The macroscopic description given by Dr. Hawes of his dike No. 2, answers almost perfectly for this dike, save that the Summit dike is darker and richer colored, the porphyritic crystals of hornblende are fresher and of a larger size than the New Hampshire specimens which I have seen. The crystals of hornblende also appear to be more numerous in the Summit dike than in the other. It is also mottled near the contact with large crystalline nodules of calcite and occasionally of feldspar. Magnetite, menaccanite and pyrite also occur.

Microscopically the rocks present no striking differences save what a macroscopic study would suggest. In some of the mottled spots of the Summit dike, however, are cavities filled with true glass into which project well-developed lath-shaped crystals of feldspar.

About twenty rods above this dike, toward the Summit station, is another dike with the same dip and strike, but wholly different in appearance from the first dike. This dike corresponds to Dr. Hawes' diabase dike No. 1. It has large amygdaloid cavities which are filled with chlorophane (?), calcite, stilbite and apophyllite. The rock is much finer grained than the first dike and shows no porphyritic crystals. The microscope shows it to consist principally of augite crystals, with a small proportion of hornblende and biotite in a feldspar magma. The feldspar is not well crystallized. The rock is badly decomposed.

In the dike first referred to as being similar to Dr. Hawes' diorite, the microscope shows that there are present a few crystals of pyroxene. This makes the two dikes at the Summit the reverse of each other. The writer feels more certain of the identity of these two dikes with the diorite and diabase of Dr. Hawes since he (the writer) made a partial chemical analysis of the Summit rock which agreed almost exactly with the analyses published in the papers cited above.

I have not time to make a thorough microscopic study of the above rocks, but shall be glad to furnish material to any one who wishes to undertake it. I have no doubt, however, that such a study would only confirm the present opinion that the Summit dike is identical with the Camptonite.

Laboratory State Geol. Survey of New Jersey.

ART. XXXIII.—*A Determination of the value of the B. A. unit of Resistance in Absolute measure, by the method of Lorenz;* by Dr. LOUIS DUNCAN, GILBERT WILKES and CARY T. HUTCHINSON.

THE work here reported upon was done at the Physical Laboratory of the Johns Hopkins University during the spring of 1888.

Lord Rayleigh's modification of Lorenz's original method was used: in this, as is well known, a measured part of the current flowing through the inducing coils is balanced by the current induced by the rotation of the disc.

The apparatus employed is that designed by Professor Rowland for his determination of the ohm undertaken for the United States Government. A detailed description of it is contained in his forthcoming report, so only a few words will be given to it here. The induction coils, four in number, were wound in square channels cut in heavy flanges, cast on the exterior of a hollow brass cylinder open at both ends. The

coils were respectively 30·171, 9·786, 10·545, and 30.775 cms. from the mean plane of the disc, itself placed as nearly as possible midway between the ends. The cylinder is about 66 cms. long, 100 cms. in diameter, and 1cm. thick; it is thus the longest ever used in work of this kind. The flanges and cylinder were cast in one piece, and the tooling was all done without once removing the casting from the lathe. The walls of the channels were left very thick to prevent spreading during the winding of the coils. The radius of the disc was so chosen that an error in its value should enter as slightly as possible in the value of the coefficient of induction.

The disc was brass, 21·5 cms. radius and ·5 cms. thick. It was fixed to a brass axle, 3 cms. diameter, turning in bearing boxes, carried by suitable framework fixed inside the cylinder. There was a cone of grooved pulleys toward one end of the axle, used for getting different speeds of the disc. The motor for running the disc was in the adjoining room about 10 meters from the disc. The speed obtained varied from 26 to 47 revolutions per second, higher than has usually been used.

The current was taken from the edge of the disc by three brushes which bore on it at angular distances of 120°; each brush was made of three or four brass strips of different lengths soldered together at one end; each strip in every brush touched the disc, one brush occupying a length of 2 cms. or more on the edge. The strips were made of various lengths in order to avoid systematic vibrations. For the contact at the center, a conical counter-boring was made in one end of the axle, and a brass point was pressed into it constantly by a stiff spring. The counter-boring in the axle, the point, the brushes and the edge of the disc were all carefully amalgamated before each observation; particular care was given to this. The insulation resistance of the coils was found to be from six to ten megohms.

The arrangement for getting the speed differed from that generally employed. As the quantity desired is the average speed during the time of an observation it seemed that a chronograph, if sufficiently accurate, would give this better than any other means, besides furnishing at a glance the history of the systematic variations of the speed, while the galvanometer showed the abrupt changes. The spot of light of the galvanometer was usually very steady, showing that there were no sudden changes. Every hundredth revolution of the disc was recorded on the chronograph; to accomplish this, one end of the axle was connected to an ordinary speed counter, consisting of a worm wheel and endless screw, which rested on a board fixed to receive it. The worm wheel carried a small brass pin, which made contact every revolution with a brass strip fixed

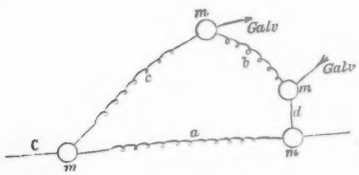
near it, thus closing the chronograph circuit. The strip was adjustable and the contact was always made as slight as possible consistent with certainty. The length of this contact about $\frac{1}{80}$ sec., while the clock break was nearly twice this.

The connection of the axle with the endless screw was made in this way: A small hard rubber screw with square head was fitted in the end of the axle and was joined to the screw of the speed counter by drawing over both a piece of pure rubber tubing with thick walls, about 2 cms. long. This connection is easily made, permits no slipping, and absorbs vibrations so completely that even for comparatively high speeds no fastening is required to hold the counter down to the board; but for the very high speeds we used, it was necessary to secure it to the rubber bed on which it lay by rubber bands, in order to ensure perfectly uniform contact between the pin and the spring.

The chronograph was a large and excellent instrument by Fauth; the drum was about 18 cms. diam. and in this work, revolved in 30 secs.; the length of a second was thus nearly 2 cms.; the sheet could be read with rough means to $\frac{1}{2}$ mm. ($=\frac{1}{4}\frac{1}{0}$ sec.,) and was actually read much closer. As each observation lasted five minutes, even this gave an estimation of the mean speed to $\frac{1}{8}\frac{1}{0}\frac{1}{0}\frac{1}{0}$.

The galvanometer was a low resistance one of the Thomson reflecting type; a small piece of wire, which dipped in a light oil, was hung from the needle and acted as a damper; with this the needle was found to be sufficiently sensitive and to come nearly to rest in about 12 secs. after reversing the current through it.

The resistance "*a*" in the figure, through which the main current flows, is a large one ohm coil of German silver wound about a skeleton cylinder of glass rods, and is about 30 cms. high and 15 cms. in diameter. The ends of the coil are soldered to copper blocks which form the bottoms of mercury cups. It is placed in an earthenware jar filled with a special light oil known to be a good insulator and is provided with a stirring paddle. Resistance "*b*" is a one ohm coil by Elliott of the usual form; this is put in a large glass jar and surrounded with water. Resistance "*c*" is taken from specially made "comparators;" each consists of ten coils of the same nominal value wound together in a copper cylinder 6 cms. diameter; they are properly insulated, etc., and protected by a



larger concentric cylinder. The terminals are soldered to the copper bottoms of mercury cups, arranged in two circles around the hard rubber ring which closes the annular space between the inner and outer copper cylinders. The inner cylinder is filled with water. The connections of the ten coils can be varied at pleasure: they can all be thrown in series, in parallel, or in any intermediate arrangement. There were two comparators used, with the coils 100 and 10 ohms respectively.

To keep the temperature constant, spirals of lead pipe were placed around the Elliott coil and in the inner cylinders of the comparators, through which there was a constant flow of water from the city supply. This answered its purpose admirably; the temperature varied only a degree or so from day to day even. The water, was of course, allowed to flow some hours before beginning observations.

The terminals of all resistances were brought to large mercury cups (m, m) each having an amalgamated copper disc lying on the bottom. The main current did not flow through any part of the circuit of the induced current; a short bridging piece (d) is used, as Lord Rayleigh found necessary.

The resistances used were all compared several times by different observers with the standard: this was a Warden Muirhead 10 ohm coil, whose value was determined at the Cavendish Laboratory in 1887; it was 9·99416 B.A. units at 16·5°, with temperature coefficient of ·000292 per ohm per degree.

In taking the observations, the aim was to adjust the resistances first so that there should be only a small deflection; after a number of galvanometer readings for this "balanced" arrangement had been taken, the resistance "c" was changed so as to give a deflection of 10 divisions (say); readings were taken for this "unbalanced" arrangement; the original "balanced" was then restored and readings taken. If nothing had changed sensibly since the beginning of the experiment, the average deflections for the two "balanced" would agree; of course, this condition was only approximated to. The "unbalanced" set gives the data for correcting for the small deflection of the "balanced."

Each experiment then consists of the galvanometer, speed, and temperature readings pertaining to the three arrangements of resistances: these three arrangements are called "A," "B," and "A′" in the order taken, irrespective of the magnitude of the deflections. In general, R_1 and R_2 (subscripts 1, 2, 3, refer to A, B, A′, respectively: R is the "effective" resistance) are the same, and the corresponding deflections are small; B is in this case used to correct both R_1 and R_2, and the mean of the corrected values is used. When, however, the deflection for

A happens to be undesirably large after beginning the experiment, B is made to give a small deflection, and A′ made as nearly as may be the same as A. We have in this case to apply the mean of two corrections to R_2, one from A and the other from A′.

In each arrangement, as A, the current is reversed four times; it is kept in the same direction for one minute at a time, and five galvanometer readings at equal intervals of time are taken each minute; this gives then 25 galvanometer readings, and occupies five minutes. The set B is begun as quickly as possible after A. The chronograph record is started by dropping the pen on the revolving drum only a few seconds before the first galvanometer reading, and an effort is made to use that portion of the record beginning exactly with the readings, the record is stopped at the instant of the last reading by lifting the pen. Temperature readings are taken before, after and often during the set. The resistance carrying the main current is constantly stirred and the others frequently. After A′, the temperature of the cylinder and disc is noted.

Variety was given to the different experiments by using different pairs of induction coils, inner or outer, and by varying the speed and direction of rotation. Sometimes, too, an experiment was repeated with everything the same, except that the resistance "c" would be made up of different coils.

The coefficients of mutual induction for the two pairs of coils as used by Professor Rowland are:—

Coils 1+4, M= 60292·5
" 2+3, M=102030·2
Diameter disc =42·1334 at 17°.

Before beginning these experiments, the disc was slightly turned off in order to smooth the edge; the diameter was measured by two observers, and was found to be

43·1201 at 17° C.

The formulæ expressing the effect on M of small changes in the quantities entering in its expression are,

$$\text{for } 1+4, \quad \frac{dM}{M} = \cdot 015\frac{dA}{A} + 1\cdot 912\frac{da}{a} - \cdot 927\frac{db}{b}$$

and

$$\text{for } 2+3, \quad \frac{dM}{M} = -0\cdot 95\frac{dA}{A} + 2\cdot 12\frac{da}{a} - 0\cdot 17\frac{db}{b},$$

where A=mean radius of the coil,
a=radius disc,
b=distance of mean planes of disc and coil.

The corrections, calculated by these formulæ, due to the change in "a" give

for 1+4, M= 60257 at 17°
and " 2+3, M=101964 "

Let ρ=ratio of the BA unit to the ohm,

$R=\frac{ab}{a+b+c}$="effective" resistance,

N=No. revolutions per second.

D=D_S-D_N=difference of mean deflections, D_S and D_N, for the two positions, S and N, of the reversing key; i. e. D would be the mean deflection for either direction of current, if no irreversible effects existed.

Then will

$$\frac{1}{\rho}=\frac{1}{MN_{1\cdot3}}\left\{R_{1\cdot3}-\frac{\frac{N_{1\cdot3}}{N_2}R_2-R_{1\cdot3}}{\frac{N_{1\cdot3}}{N_2}D_2-D_{1\cdot3}}D_{1\cdot3}\right\} \quad (1)$$

and

$$\frac{1}{\rho}=\frac{1}{MN_2}\left\{R_2-\frac{\frac{N_{1\cdot3}}{N_2}R_2-R_{1\cdot3}}{\frac{N_{1\cdot3}}{N_2}D_2-D_{1\cdot3}}D_2\right\} \quad (2)$$

(1) is used when $D_1 \leqslant D_2$
(2) " " $D_1 > D_2$.

The double subscripts, as $R_{1\cdot3}$, means that the two quantities R_1 and R_3 are to be used in turn; that is to say, each formula above is really double: first, we use the sub 1's, and then the sub 3's. It was found more convenient to calculate the values of ρ_1 and ρ_3 this way and average them, than to apply an average correction. Indeed, when the speeds N_1 and N_3 are different, this is the only way.

The following table gives the data and results of these experiments; the (+) direction of rotation is, —Zenith, North, Nadir, South.

Experiments Nos. 1, 2, 3, 6, 14A′, 17A′ and 22 were interrupted by divers accidents and never completed; in No. 19, there is confusion in the notes making the sign of the deflection doubtful; Nos. 21, 23 and 24, give values of ρ from 2 to 10 per cent out, due to some error in the record of resistances used. This accounts for all the experiments begun.

The average of all the above is ·98622; without No. 27, which differs about twice as much from the mean as any other observation, the average is ·98634. The great divergence of No. 27, is in itself reason enough for giving it less weight; but in addition, the chronograph sheet shows that the speed here was very irregular, increasing, decreasing and increasing

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Descp.	Coils.	Rotat'n.	N.	D.	R.	Correction.	Corrected resist.	M.	ρ.
A	1 and 4	+	35·648	+ 4·74	·00220207	−·00002110	·00218097	60266	
4 B			·701	− 6·71	215435				·98620
A′			·715	+ 6·04	220216	−·00002215	217991		
A	2 and 3	+	·720	−10·76	365835	−·00000828		101979	
7 B			·966	+ 2·60	372638		371810		647
A′									
A	"	+	·752	+10·15	372859	−·00003345	369514	"	
8 B			·929	− 6·15	369317				658
A′			36·055	+ 0·37	372859	−·00000127	372732		
A	"	−	·268	+ 5·24	372837	+·00001695	374532	"	
9 B			·162	+12·51	369392				725
A′			·347	+ 7·99	372837	+·00002712	375549		
A	"	+	·514	+ 2·16	376476	+·00000513	377007	"	
10 B			·462	+14·39	372933				758
A′			·503	+ 1·94	376476	+·00000486	376962		
A	"	+	35·373	+ 4·12	365589	+·00000559	366188	101974	
11 B			·365	− 9·70	367517				490
A′			·497	+14·96	365589	+·00001999	367588		
A	"	+	·066	− 8·19	365680	+·00000560	363586	"	
12 B			·134	+ 1·64	363026				541
A′			34·959	−11·91	365680	+·00000551	363577		
A	"	−	35·053	+ 0·53	362375	−·00000230	362145	"	
13 B			·099	+ 7·10	365710				724
A′			·200	− 2·49	362375	+·00001137	363512		
A	"	−	34·249	− 9·08	362865	+·00000267		"	
14 B			·184	− 2·56	352873		353140		710
A′									
A	"	−	·621	−14·88	352932	−·00000282	359439	"	
15 B			·752	+ 0·81	359721				594
A′			·844	− 8·84	357139	−·00000297	359424		
A	1 and 4	+	·999	+ 0·42	213697	+·00000154	213851	60232	
17 B			·928	− 6·20	215248				710
A′			·715	− 5·47	213697	− 00001939	211758		
A	"	−	·767	− 6·23	210691	−·00000604	212373	60263	
18 B			·745	+ 2·07	212977				583
A′			·731	− 6·05	210691	−·00000562	212415		
A	"	+	26·630	+ 0·52	162529	+·00000156	162685	60265	
20 B			·943	− 6·54	169446				659
A′			·744	+ 2·77	162529	+·00000817	163346		
A	"	−	40·486	+ 0·55	247395	+·00000351	247746	60267	
25 B			·626	+20·29	235649				472
A′			·450	+ 0·32	247395	+·00000206	247601		
A	2 and 3	−	·033	− 2·88	411309	+·00002574	413883	101970	
26 B			·478	+17·48	402846				651
A′			·537	+ 0·74	419576	−·00000654	418922		
A	"	+	·933	+ 1·15	422586	+·00001644	424230	"	
27 B			·906	+ 8·81	411344				372
A′			41·130	+ 2·65	422586	+·00003836	426422		
A	"	+	26·833	+ 2·19	274840	+·00002602	277442	"	
28 B			·654	+12·75	260443				
A′			·861	+ 2·31	274840	+ 00002711	277551		653
A	"	−	25·885	− 0·25	267436	−·00000151	267285	"	
29 B			26 076	− 9·30	274869				
A′			·240	+ 5·94	267436	+·00003557	270993		745
A	"	−	30·024	+ 1·59	308948	+·00000925	309873	"	
30 B			·125	+19·12	299648				
A′			·220	+ 5·30	308945	+ 00003193	312138		762
A	"	+	29·831	− 3·05	306612	+·00001857	308469	"	
31 B			30·053	+13·41	318928				
A′			·504	+ 0·13	311446	−·00000078	311368		601
A	"	+	47·531	+ 1·51	492544	−·00000882	491662	"	
32 B			·514	−18·56	480642				551
A′			·545	+ 0·74	492544	−·00000444	492100		
A	1 and 4	+	·513	+ 0·53	290981	−·00000234	290747	60271	
33 B			·869	+15 12	299749				457
A′			·457	+ 0·83	290981	−·00000363	290618		

again; this is the only occurrence of such irregularity. Therefore giving it about one-third weight, we find as the most probable value

1 B. A. UNIT = ·9863 OHMS.

A determination of the "Mercury Unit" was recently made by Messrs. Hutchinson and Wilkes (Johns Hopkins University Circulars, May, 1889), who found the value to be

·95341

taking this with the above number for the B. A. unit, we have as the length of the mercury column corresponding to the ohm,

106·34 CMS.

ART. XXXIV.—*The Properties of Allotropic Silver;* by M. CAREY LEA.

THE three forms of allotropic silver which were described in the June number of this Journal—the blue soluble and the blue and the yellow insoluble—are not to be understood as the only forms which exist, but as the best marked only. The substance is protean, and exhibits other modifications not yet studied. No other metal than silver appears to be capable of assuming such a remarkable variety of appearances. Every color is represented. I have obtained metallic silver blue, green (many shades of both), red, yellow and purple. In enumerating these colors I do not refer to interference colors produced superficially by reagents, also wonderfully brilliant, but to body colors. As a single instance of coloration the following may be mentioned. I recently obtained a solution of allotropic silver of an intense yellow brown. A little solution of disodic phosphate changed this to bright scarlet (like Biberich scarlet) presently decolorizing with formation of a purple precipitate. Washed on a filter this changed to bluish green. The colors I have met with in this investigation can only be compared with the coal-tar products, of which one is constantly reminded by their vividness and intense colorific power.

Two of the insoluble forms of allotropic silver, the gold-colored and the blue, show in many respects a close relationship and almost identical reactions. There are other respects in which they differ strikingly and amongst these, in stability. Blue allotropic silver (dark red whilst moist, becoming blue in drying) is very stable. It may be exposed for weeks in a

moist state on a filter, or be placed in a pasty condition in a corked vial and so kept moist for months, without alteration.

The gold-colored form on the contrary, tends constantly to revert to ordinary silver. This is especially the case whilst it is moist, so that from the time of its formation, it must be separated from its mother water and washed as rapidly as possible, otherwise it loses its brilliancy and purity of color and changes to a dark dull gray form of normal silver. On the filter, its proper color is pure black with a sort of yellow shimmer (the gold color appearing as it dries) often, especially if allowed to become uncovered by the water during washing, it will change superficially to gray.* But if the washing is done rapidly with the aid of a filter pump and a pressure of four or five inches of mercury, the allotropic silver obtained, when allowed to dry in lumps, or brushed over paper or glass, is at least equal to pure gold in color and in brilliancy. With the blue product such precautions are wholly superfluous.

Of the facility with which the gold colored form is converted into normal silver, I have recently had a somewhat singular proof. I brought with me to my summer home a number of specimens in tubes, some recently prepared, some dating back as far as two and a half years, together with other tubes containing specimens of white silver spontaneously formed from the gold colored. On opening the box no tubes of gold colored silver were to be found, all had changed to white. But the same box contained pieces of paper and of glass on which the same material had been extended; these were wholly unchanged and had preserved the gold color perfectly. Apparently the explanation was this, the mere vibration caused by the jarring of a journey of 600 miles by rail and steamboat had had no effect in changing the molecular form, but the material contained in the partly filled tubes had been also subjected to *friction* of pieces moved over each other, and this had caused the change. To verify this explanation I prepared fresh material, filled three similar tubes each one quarter full, but in one forced in cotton wool very tightly to prevent frictional motion. These tubes were packed in a small box and sent over 2400 miles of railway. The tubes with loose material came back much altered, one was nearly white, and as the change has been set up will probably in a few days be entirely so,† another with loose material was also changed but not as much as the first mentioned. The tube filled up with cotton came back unaltered. So that continued friction of pieces sliding over each other will cause a change to take place in a few days which otherwise might have

* When well washed, this form can also be preserved for a time in the moist condition in a corked vial, as I have lately found.

† Has since become so.

required years or might not have occurred at all. The permanency of this substance is greatly influenced by moisture, so that when simply air-dried before placing in tubes it is less permanent than when dried at 70° or 80° C. in a stove. Tubes placed in the same box containing the blue form remained unaffected by the motion, though only partly filled and allowed to move freely.

When gold-colored allotropic silver is gently heated in a test tube it undergoes a remarkable change in cohesion. Before heating, it is brittle and easily reduced to fine powder. After heating it has greatly increased in toughness and cannot be pulverized at all.

Both the gold-yellow and the blue forms resemble normal silver in disengaging oxygen from hydrogen peroxide.

These two forms though differing so much in color and stability and differing also in specific gravity and in their mode of formation, have many properties in common, not possessed by ordinary silver, and differentiating them strongly from it. They show a vastly greater sensitiveness to reagents, and are also sensitive to light. The ability to form perfect metallic mirrors by being simply brushed in the pasty condition over glass was mentioned in a previous paper.

Many substances which react little if at all with ordinary silver, attack the gold-colored and the blue allotropic silver with production of very beautiful colors due to the formation of thin films and resulting interference of two reflected rays. In my previous papers I called this the "halogen reaction" because first obtained by the action of substances which easily parted with a halogen. But I have since found that many other reagents will produce the same or similar effects. These are

Sulphides. Paper brushed over with either the gold, the copper colored, or the bluish green substance exposed to the vapor of ammonium sulphide, or immersed in a dilute solution of it, assume beautiful hues, though less brilliant than those obtained in some other ways.

Potassium permanganate in dilute solution produces blue, red and green colors.

Potassium ferricyanide in moderately strong solution gradually attacks allotropic silver with production of splendid blue, purple and green coloration.

Phosphorous acid produces gradually a rather dull coloration.

The color reaction is produced finely by substances which readily part with a halogen such as ferric and cupric chlorides, sodium hypochlorite, hydrochloric acid to which potassium bichromate has been added, and by corresponding, bromine

and iodine compounds. In some earlier experiments I obtained effects of the same sort, but in much weaker degree with alkaline haloids. But with purer products, the results have been different. There is at first some darkening, but no true color reaction and the allotropic silver appears to be gradually converted into normal, so that it is no longer capable of giving the brilliant color reaction with potassium ferridcyanide, but, like normal silver, takes a pale and faint coloration only.

The perchlorides of platinum, gold and tin do not give the color reaction, though by analogy one would expect that they should, since they can lose chlorine with formation of a lower chloride.

Action of Light.—In a previous paper was mentioned the remarkable fact that the gold- and copper- colored forms of allotropic silver can be converted first into yellow and finally into white normal silver by the continued action of light. The earlier specimens of the blue form became brown by exposure, but purer ones since obtained are likewise converted into yellow by exposure, becoming continually lighter as the action is continued. The conversion from the darker shades to a bright yellow with full metallic luster is very easy, but when the previous paper was written I had been only able to obtain the white by keeping the paper, on which the silver was coated, moist by a wet pad and by exposing for five or six days. Since then I have obtained the gold-colored silver in a more sensitive form, giving a perfectly white product by exposure dry for half that time.

The white silver thus obtained has all the character of ordinary silver and does not show the color reaction with ferric and cupric chloride, potassium ferridcyanide, etc. Just in proportion to the exposure to light, the ability to give this color reaction diminishes, so that after a day's exposure, when the exposed part has become bright yellow, the color reagents scarcely affect this yellow, whilst the protected part becomes intense blue, purple, or green. In this way it is easy to observe the gradual effect of light as it changes the allotropic silver, finally converting it into what resembles in every way, and is undoubtedly, ordinary silver.

July, 1889.

ART. XXXV.—*On Ring Systems and other Curve Systems produced on Allotropic Silver by Iodine;* by M. CAREY LEA.

ALLOTROPIC silver, in its moist and plastic state, may be brushed over paper and gives on drying a continuous and brilliant coating resembling metallic leaf.* When a small crystal of iodine is placed on paper that has been thus coated, a system of colored rings of remarkable beauty is obtained. A funnel or beaker should be inverted over the paper to prevent distortion by irregular currents of air. One form of distortion, however, produced by a slight current in one direction, gives interesting results. If the paper with the crystal on it is set near a closed window, the slight current which makes its way through, affects the air under the glass enough to carry the iodine vapor principally in one direction and there result oval or pear-shaped curves of great elegance and much variety according as the air currents are stronger or weaker. Another method is to place a bell glass, not fitting too closely, over the paper and to set it where it will be influenced by the draught created by a fire, or even by a gaslight.

That iodine is capable of producing interference rings (Nobili's rings) on metallic surfaces has long been known, and Robert Hunt has described their formation on surfaces of normal silver. I have made these for comparison, pressing gummed paper on silver leaf, bringing to a smooth surface by gently rubbing after drying. The contrast between the pale and faded-looking effects produced on normal silver, and the lustrous and glowing hues given by the allotropic, is very striking.† One cannot help wishing that this splendid coloration could be made to do service for obtaining natural colors by photographic processes.

As to the durability of these products, I cannot yet speak with positiveness. Protected from light and air they endure for several months at least. Both the bluish green insoluble silver B, and the gold-colored C produce these effects; the gold-colored is the better suited of the two.

July, 1889.

* Described in this Journal, June, 1889.

† I was desirous of having some of these curve systems reproduced in color printing for this Journal, but on conferring with an experienced color printer, found that he could give no assurance of a successful result. The colors are transparent, and yet have a metallic brilliancy, a combination almost impossible to imitate in printing.

ART. XXXVI.—*Notes on some Native Iron Sulphates from Chili;** by JAMES B. MACKINTOSH.

IN March, 1887, I received from Dr. Thos. Egleston a series of the native iron sulphates from South America, which I analyzed for him, as there were some minerals among them which he was not able to identify and which he regarded as probably new. It is with his permission that I now give the results of my analyses and the conclusions to which they lead. My results confirm his opinion as to the novelty of some of the specimens analyzed.

Among the series of specimens were several of well known species, of which I also made analyses. These I will give first, with but little comment, as they do not afford much that is new, and then take up the new varieties in turn.

1. *Coquimbite.*—Of this species I had three varieties, as described below, which gave the following results:

	I (No. 1). Amethystine crystalline transparent.	II (No. 2). Amethystine massive translucent.	III (No. 10). White massive opaque.
Specific gravity	2·07	2·086	----
SO_3	43·40	42·90	42·32
Fe_2O_3	22·17	26·10	28·10
Al_2O_3	4·39	1·65	SiO_2, Al_2O_3 0·91
Na_2O	0·25	0·27	----
CaO, MgO	traces	traces	----
H_2O (difference)	[29·79]	[29·08]	[28·67]

All lead to the same formula, Fe_2O_3, $3SO_3$, $9H_2O$. The water expelled at 110° in the three samples was 5, 6, and $5\frac{1}{8}$ molecules respectively. It is interesting to notice that the most crystallized and transparent specimen is the poorest in iron and richest in alumina, while the most opaque and non-crystallized is the richest in iron.

2. *Copiapite* (No. 6).—The specimen analyzed was massive, yellow, with specific gravity = 2·118. The analysis gave

SO_3	39·03
Fe_2O_3	29·16
FeO	1·56
Na_2O	0·31
H_2O	[29·94]

* Recent contributions to our knowledge of the iron sulphates of South America have been given by Frenzel, on amarantite and hohmannite, Min. petr. Mitth., ix, 397, 1887; and by G. Linck on coquimbite, copiapite, quenstedtite, stypticite, roemerite, halotrichite, Zeitschr. f. Kryst., xv, 1, 1888.

The formula corresponds to

$$91\{2Fe_2O_3, 5SO_3, 18H_2O\} + 22\{FeSO_4, H_2O\} + 5\{Na_2SO_4, H_2O\}$$

The water lost at 110° C. is 1124 out of 1663 molecules represented in the above formula or about 12 out of each molecule of $2Fe_2O_3$, $5SO_3$, $18H_2O$ or $\frac{2}{3}$ of total H_2O. Readily soluble in water before and after heating to 110°.

3. *Roemerite* (No. 8).—Brown, crystalline; specific gravity 2·15; analysis gave:

		Ratio.
SO_3	40·19	50·24
Fe_2O_3	19·40	12·125
FeO	9·52	13·22
Na_2O	0·14	0·226
H_2O	[30·85]	171·39

After subtracting SO_3 corresponding to Na_2O present, the molecular ratio is 4 : 0·97 : 1·058 : 13·7 or nearly 4 : 1 : 1. At 110° C. most of the H_2O is expelled with simultaneous oxidation of part of the ferrous iron. The net loss amounts to 11·8 molecules of H_2O. leading to the formula FeO, Fe_2O_3, $4SO_3$, $13·7H_2O$ ($12H_2O$ Tschermak, $15H_2O$ Linck). Readily soluble in water—after heating only partially soluble.

4. *Amarantite* (No. 3).—Red, crystalline, with sp. gr. = 2·005; associated with copiapite. Analysis:

		Ratio.
SO_3	36·15	2·0
Fe_2O_3	35·69	0·987
Al_2O_3	0·21	0·009
Na_2O	0·51	0·036
H_2O	[27·44]	6·75

Hence the formula corresponds to

$$Fe_2O_3, 2SO_3, 7H_2O$$

When heated to 110° C., 3·48 molecules of water are expelled and the residue leaves a slight insoluble basic salt on solution in water.

5. We will now consider some minerals which have not yet been described and which are of seemingly definite formula. The first of these (No. 9) occurs associated with copiapite and amarantite, but quite distinctly separated from them, in pulverulent orange flakes which are arranged in parallel tabular layers. It shows no crystalline structure, which might be expected if it was a direct alteration of amarantite, and there is a sharp line of demarcation between the minerals on the same specimen with no appearance of a transition state. Analysis gave:

		Ratio.
SO_3	41·24	2·001
Fe_2O_3	41·22	1·000
H_2O	[17·54]	3·78

Formula Fe_2O_3, $2SO_3$, $4H_2O$

Water lost at 110° C. = 0·304 molecule, leaving a residue containing 3·48 molecules. The result of heating this mineral is the same as of heating amarantite. They only differ by 3 molecules H_2O, but there is no apparent structure like amarantite to indicate that the one is a direct product of dehydration of the other.

6. *Ferronatrite* (No. 11).—The analysis of this mineral I have recently completed, having received it from Prof. Egleston only a short time since. It occurs in stellate groups of a pale, whitish green color, forming nearly spherical nodules; it is in general similar to pale wavellite in appearance. It is associated with copiapite and coquimbite. Analysis:

		Ratio.
SO_3	50·25	6·281
Fe_2O_3	17·23	1·077
Al_2O_3	0·43	0·042
Na_2O	18·34	2·958
K_2O	0·40	0·042
SiO_2, etc., insoluble	2·00	
H_2O	11·14	6·189
	99·79	

Formula $3Na_2O$, Fe_2O_3, $6SO_3$, $6H_2O$

Water lost at 110° = 5½ molecules, the residue dissolves readily in water. This mineral is somewhat similar to sidero-natrite, Na_2O, Fe_2O_3, $3SO_3$, $6H_2O$, to urusite, $2Na_2O$, Fe_2O_3, $4SO_3$, $8H_2O$ and to bartholomite, $2Na_2O$, Fe_2O_3, $4SO_3$, $2H_2O$, but differs from them in being soluble in water and being a neutral instead of a basic salt. It is quite analogous, however, to Kröhnkite,* the double sulphate of sodium and copper if we can consider that the copper may be replaced by its equivalent in ferric iron without destroying the analogy. The relationship is clearly shown by the formulæ, taking 3 parts of Kröhnkite.

Kröhnkite	$3(Na_2O, CuO, 2SO_3, 2H_2O)$
Ferronatrite (new mineral)	$3Na_2O$, Fe_2O_3, $6SO_3$, $6H_2O$

7. Associated with these minerals are several white pulverulent sulphates which are apparently alteration products, but which nevertheless possess some points of interest. Of these the first gives the following results on analysis. White, pulverulent (No. 4), sp. gr. not taken. Analysis:

* Cf. Darapsky, Jahrb. f. Min., i, 192, 1889.

		Ratio.
SO_3	38·00	6·25
Fe_2O_3	12·16	1·00
FeO	22·51	4·114
Na_2O	0·58	1·124
H_2O (by difference)	26·75	19·55

Formula $3FeO, Fe_2O_3, 5SO_3, 18H_2O + FeO, SO_3, H_2O$

or $4FeO, Fe_2O_3, 6SO_3, 19H_2O$

Water lost at 110° C. = 9·61 molecules. This cannot be regarded as a mixture of $4FeSO_4$, Aq. and (Fe_2O_3, $2SO_3$, Aq.) because it is *perfectly white* and not red or yellow-brown, which would be the case if it was a mixture containing amarantite or No. 9. Another argument in favor of its individuality seems to be the loss of one-half its water at 110° C. It bears a certain similarity to copiapite, which suggests that it may be a product of partial reduction of, or of action of ferrous sulphate on, copiapite. This view does not seem to me to be far fetched, since the analysis of the copiapite, quoted above, shows the presence of a small quantity of ferrous sulphate. If we write copiapite $2Fe_2O_3, 5SO_3, 18H_2$ it is seen that by the substitution of $3FeO$ for $1Fe_2O_3$ in the above formula, with simultaneous addition of another molecule of $FeSO_4$ we would arrive at the formula adopted, viz:

$$3FeO, Fe_2O_3, 5SO_3, 18H_2O + FeO, SO_3, H_2O$$

8. Two other white powders associated with these minerals have given the following figures:

	A.	Ratio.	B.	Ratio.
SO_3	47·90	599	45·61	570
FeO	30·81	428	35·05	487
Fe_2O_3	5·64	35	5·14	32
Al_2O_3	0·65	6	----	---
Na_2O	4·42	71	0·33	5
H_2O (difference)	10·58	588	13·87	770

These both have as their chief constituent a ferrous sulphate with one molecule of water, as shown below:

A $428(FeSO_4, H_2O) + 71Na_2SO_4 + 40(2Fe_2O_3, 5SO_3, 4H_2O)$

B $487(FeSO_4, H_2O) + 5Na_2SO_4 + 16(2Fe_2O_3, 5SO_3, 18H_2O)$

In the first of these this monohydrated ferrous sulphate amounts to about 70 per cent of the material and in the second to about 78 per cent. This same compound also appears in the copiapite analysis. This form of ferrous sulphate is far more stable than melanterite, which, indeed, changes into this form very readily by loss of water when protected from oxidizing influences.

SCIENTIFIC INTELLIGENCE.

I. PHYSICS.

1. *Electrical Waves in Conductors.*—In continuation of his work upon electrical waves, or surgings, as Lodge expresses it, HERTZ has examined experimentally the theoretical conclusions of Maxwell, Heaviside, Poynting and others in regard to the distribution of an electrical current upon the surface and through the section of a wire carrying it. It is well known that a steady current distributes itself through the cross section of the conductor. When the current however is oscillatory in its nature the distribution ceases to be uniform through the section, and when the current changes its direction many millions of times a second the electricity glides upon the surface of the conductor or spreads inward from the surface, according to laws analogous to those governing the increase of temperature from the surface of the earth to its interior. The slower the changes of current the deeper the penetration of the electricity into the interior of the wire. Hertz finds the theoretical conclusions fully justified by his experiments. His apparatus was similar to that employed in his earlier researches. Electrical waves of three meters long were produced. Their nodal points were detected by the spark method. In one experiment a space along the wire upon which the electrical oscillations were produced was replaced by two strips of thin metal connected at their ends with the wire. Between them was a stretch of insulated wire with a spark interval between the ends. No spark jumped across these ends when the wire was almost entirely surrounded by the tin foil, the wire being then in the center of the conductor. When, however, the smallest portion of the wire was outside, the tin foil sparks appeared. In order to make these sparks disappear it was merely necessary to wrap the exposed portion of the wire with tin foil and connect this with the main leading wire. In this case, we have brought the wire back into the interior of the conductor. In another experiment the conductor, which was of very thick copper of 1·5 meters in length, had interposed two metal discs, separated by a short interval. In the interval were two knobs for the passage of sparks. Sparks passed freely when the waves were produced. When, however, the discs were connected by wires passing through corresponding holes in the discs, near the edges and opposite to each other, the spark decreased in length. When wires connected the edges of the discs outside the wires passing through the holes, the sparks decreased still more in length, and when a number of wires connected a number of holes, and wires were placed outside these wires along the edges of the disc, no spark passed in the interior of the cylindrical cage, although the resistance of the exterior wires was greater than the interior wires. The electricity passed along the exterior wires and not through the interior ones. By means of a similar

arrangement thin cylinders of various metals enclosed a portion of the wire upon which the electrical waves were excited. These thin cylinders protected the inner wire from electrical disturbances. Thin deposits of silver on glass cylinders which allowed light to be seen through them did not entirely shield the inner wire. When the thickness of the silver layer increased to only $\frac{1}{100}$ of a millimeter all sparks disappeared in the spark detector, showing that the electrical disturbance was entirely on the surface of the conductor. Instead of saying, therefore, that electrical waves are propagated through the wires, we should say that they glide along the surface of the wire. Further experiments are added which conclusively show that the electrical waves are confined to the surface of the conductor, and that they are greatly influenced upon two neighboring conductors by the character of the intervening space and by surrounding objects. Hertz concludes with the observation that, according to former ideas, he classed among conductors those substances which allowed the passage of electricity, and among insulators those that did not permit this passage. According to the new interpretation of electrical oscillations or waves, all electrical waves are propagated through insulators, and good conductors oppose the quick oscillations of these waves. The terms conductors and insulators therefore should change places.—*Ann. der Physik und Chemie*, No. 7, 1889, pp. 395–408. J. T.

2. *Disintegration of Surfaces by means of the Ultra Violet rays.*—Philipp K. Lenard and Max Wolf, by means of Helmholtz's modification of Aitken's apparatus (Wied. Ann., xxxii, p. 1, 1887), show that the ultra violet rays exert a remarkable effect in producing dust from metallic surfaces. As a source of light sparks from a Ruhmkorf coil were used, it having been shown that these sparks are richer in violet rays than other sources of light, and have the advantage of not causing heat and are therefore to be preferred to the voltaic arc formed between carbon and zinc, which has been used by some observers. The presence of the dust was shown by the vapor produced in a suddenly exhausted receiver according to the method of Aitken, and also by the coloration of a jet of steam. The latter method Helmholtz had shown to be very sensitive, showing by changes of color the presence of metallic dust. All metals examined when negatively electrified showed metallic dust under the influence of ultra violet rays. Quartz and gypsum also showed disintegration. Fluids also when negatively electrified gave forth finely divided particles.—*Ann. der Physik und Chemie*, No. 7, 1889, pp. 443–456. J. T.

II. Geology and Mineralogy.

1. *Eruption of Baldai-san, in northern Japan, on July* 15, 1888.—This eruption, noticed in vol. xxxvi of this Journal, is reported on by Mr. Y. Kikuchi in the third volume of the College of Science Journal of the Imperial University, of Tokyo. The facts were briefly these:

The mountain of Baldai-san was an extinct volcano, but had one steaming fissure. On the 14th of July, at 10 A. M., the spring at the Spa on the mountain became dry. The next morning, the 15th, it was full again. At 7 h. of that morning, light earthquake-like rumblings were noticed; at 7 h. 30 min., there were loud and heavy shocks; at 7 h. 45 min., the eruption began, about 120 yards from the steaming fissure. A dense column of steam and dust shot up with tremendous noise. 15 to 20 explosions occurred of a minute or more each, and the vapor and dust were projected to a height of 4000 to 14000 feet, and spread into a canopy of much greater height, making pitchy darkness around. About the crater, a tempest raged of hot blasts of steam, wind, thunder, lightning, volcanic dust and falling stones, and, for five minutes, rain; the prostrated trees fell with their heads away from the crater. Within fifteen minutes of the outbreak a land-slide started from the summit, probably promoted by the shower of water, stones and rock-masses, and descended with terrific speed, burying the Nagase valley with its villages, and devastating an area of 27 square miles. Some of the masses transported by the land-slide were over 30 feet each way.

The violence was ended in less than an hour, when the darkness became that of twilight on a rainy evening; and in five hours the dust-fall had wholly ceased. The dust was drifted southeastward to the seacoast, where, 62 miles from the volcano, the area covered was 30 miles wide; but the deposit made there only traces of a film over the surface, and was but a foot deep on the leeward slope of the mountain. This dust was not ordinary glassy volcanic ashes, but like dust from abraded volcanic rock. There was no flow of lava.

Mr. Kikuchi concludes from the absence of any lava-flows and the character of the dust, that no lava was concerned in the eruption. In that case, unlike the explosive eruptions of Krakatoa and Tarawera, the vapor producing the explosions was generated above the level of liquid rock, the opened fissure permitting entrance of water only to a depth short of that where fusion existed. The chief rending and projecting force of the explosion would, in any case, have been below at the depths where the sudden generation of the vapor took place; and from the subterranean region, the rocks and stones, and the dust that abrasion could make, would have been thrown into the air to fall around, the lighter part to be drifted by the winds as it fell. The steam, after escaping into the air, would have already expended the chief part of its energy and could therefore have produced comparatively little effect on the outside walls or the summit peaks of the mountain. There would have been undermining by the ejections, and a corresponding loss to the mountain from subsidence; and there could not have been the supposed "blowing away" of even the millionth part of "2782 million tons" from the summit, the amount estimated as lost by the mountain.

Such an eruption is a *semi-volcanic* explosive eruption, suppos-

ing no lava concerned. But those fifteen to twenty explosions, a minute or more in duration, with their throws of dust and steam and apparent regularity of interval, suggest that possibly lava was concerned. For they are very like the explosions and projectile action of confined accumulations of steam on breaking through viscid lavas.

From an analysis and the optical characters of the rocks of the volcano it was made to consist chiefly of labradorite and augite. An analysis by Professor T. Wada, Director of the Geological Survey, obtained, Silica 59·56, alumina 16·10, Fe_2O_3 6·28, FeO 3·62, Mn_3O_4 1·80, lime 6·32, magnesia 3·08, soda 3·09, potash 0·80, phosphoric acid 0·18, loss by ignition 0·44=100·67. J. D. D.

2. *Mastodon or Elephas with fragments of charcoal at Attica, Wyoming Co., N. Y.*—The Report for 1887 of the State Museum of New York, contains an account, by Professor J. M. Clarke, of the discovery of bones at Attica, including a tusk and ribs, and a portion of the zygomatic arch, associated with fragments of charcoal and a piece of pottery. They were obtained from a bed of unlaminated clay, 1 foot 5 inches thick, lying beneath, 1 foot 7 inches of clayey muck and loam and 2½ feet below the natural surface. Another place, about one hundred yards distant, charcoal and the pottery were found at the bottom of a deep accumulation of muck, under which was a bed of compact clay. The depth below the natural surface of the ground was four feet. The vegetable mould was continuous between the two localities.

3. *Illustrations of the Fossil Fishes of the Devonian Rocks of Canada;* by J. F. Whiteaves, F.G.S. Part II. *Descriptions of species from the Upper Devonian rocks of Scaumenac Bay.* 20 pp. 4to, with plates V to X. Montreal, 1889. Trans. Roy. Soc. Canada, vi.—Part I of Mr. Whiteaves appeared in 1887. This second part describes and finely figures the species *Glyptolepis Quebecensis, Eusthenopteron Foordi, Cheirolepis Canadensis, Bothriolepis Canadensis, Acanthodes affinis, Phaneropleuron curtum, Cephalaspis Campbelltonensis, Coccosteus Acadicus, Ctenacanthus latispinosus, Homacanthus gracilis.*

In the Annals and Magazine of Natural History for August, p. 183, Mr. A. Smith Woodward remarks that the species of Ctenacanthus and Homacanthus are in every respect closely like the spines of the Acanthodian genus *Climatius*, as elucidated by Egerton and Powrie, and names them provisionally *Climatius latispinosus.*

4. *Brief notices of some recently described minerals.*—Michellévyte. Barium sulphate crystallizing, according to the determination of A. Lacroix, in the monoclinic system. It occurs in lamellar masses in a crystalline limestone near Perkins' Mill, Templeton, Quebec. Three cleavages are noted: *a* (100) easy, also *b* (010, plane of symmetry) vitreous, and *c* (001); the angles are $ab=bc=90°$, $ac=77°-78°$. Polysynthetic twinning, with *a* as the twinning plane, gives rise to numerous hemitropic bands observed on *b*. The optic axial plane is normal to *b*, and the

bisectrix probably coincides with the orthodiagonal axis; axial angle about 90°. Mean refractive indices 1·6413 for yellow, and 1·6305 for green. Specific gravity, 4·39. The composition is that of normal barite, $BaSO_4$. The close similarity between the two substances in cleavage form makes a more thorough knowledge of their relation to be desired. The mineral is named after M. Michel Lévy.—*C. R.*, cviii, 1126, May 27, 1889.

FLINKITE. A hydrous manganese arseniate from the Harstig mine, Pajsberg, Sweden, described by A. HAMBERG. It occurs in orthorhombic crystals, tabular parallel to the base, often grouped in feather-like aggregates. Hardness, 4·5. Specific gravity, 3·87. Color, greenish brown. An analysis gave:

As_2O_5	Sb_2O_5	Mn_2O_3	Fe_2O_3	MnO	CaO	MgO	H_2O	
29·1	2·5	20·2	1·5	35·8	0·4	1·7	9·9	=101·1.

For this the formula $4H_2O.4MnO.Mn_2O_3.As_2O_3$ is calculated, which brings it very near synadelphite. Named after the Swedish mineralogist G. Flink.—*Geol. För. Förh.*, xi, 212, 1889.

DAVIESITE. A new oxychloride of lead from Sierra Gorda, Chili, named by L. FLETCHER after Thomas Davies of the British Museum. It was observed associated with percylite and caracolite in minute prismatic crystals. These are clear and colorless and have an adamantine luster. The axial ratio is $a:b:c=1·2594:1:0·6018$. A qualitative analysis was impossible, but the crystallographic examination showed that the mineral was not to be united with any of the other known lead oxychlorides.—*Min. Mag.*, viii, 171, May, 1889.

DUDGEONITE. A hydrous arseniate of nickel named by HEDDLE after Mr. Dudgeon who discovered it at the Pibble mine, near Creetown, Kilcudbrightshire, Scotland. It is a dull, loosely coherent earthy mineral of grayish white color with spots of pale pink or green, and resinous luster; hardness, 3–3·5. An analysis gave:

As_2O_5	NiO	CoO	CaO	H_2O	
39·33	25·01	0·76	9·32	25·01	=99·43.

This corresponds to an annabergite with one-third the nickel replaced by calcium.—*Ibid.*, p. 200.

HYDROPLUMBITE. A name given by HEDDLE to a supposed lead hydrate known on a single specimen, probably from Leadhills It is inferred to be $3PbO.H_2O$, but the examination is too incomplete to allow of any definite conclusion.—*Ibid.*, p. 201.

PLUMBONACRITE. A name suggested by HEDDLE for a hydrous lead carbonate from Wanlockhead, near the hydrocerussite of Nordenskiöld. An analysis gave:

	CO_2	PbO	H_2O	Insol.	
$\frac{2}{2}$	4·76	92·85	2·01	0·78	=100·40.

ANTHOCHROITE. A silicate of magnesium, calcium and manganese from Jakobsberg, Sweden, described by L. J. IGELSTRÖM. It occurs with brannite in massive forms, having a fine granular or indistinctly crystallized structure. The color is rose-red or violet; the hardness, 5 to 6. An analysis gave:

SiO_2	MnO	CaO	MgO	Al_2O_3, Fe_2O_3	Alk.
51·6	3·4	23·3	13·5	1·4	[6·8]=100.

It seems to belong with the pyroxenes.—*Jahrb. Min.*, ii, 36, 1889.

PLEONECTITE. A partially examined mineral from the Sjö mines, Grythyttan parish, Sweden. It occurs in narrow veins with arseniopleite; color, grayish white; luster, greasy; hardness, 4. Qualitative trials led to the conclusion that it was an antimonio-arseniate of lead, carrying some chlorine.—*Ibid.*, p. 40.

5. *Lehrbuch der Mineralogie* von Dr. C. HINTZE. Erstes Lieferung, pp. 1–160, Leipzig, 1889 (Veit & Co.).—The publication of the first part of a new Descriptive Mineralogy which promises to be, when completed, the most exhaustive work ever written, is an event of no small importance to those interested in this science. This great labor has been undertaken by Prof. C. HINTZE, of Breslau, and if the whole can be carried through with the same care, accuracy and thoroughness exhibited upon each page of this first part it will be a monumental work, reflecting great credit upon its author and of great value to all workers in mineralogy. The plan as announced contemplates the issue of two or three parts yearly (at 5 marks each), the completion of the whole in two volumes being accomplished in three or four years. The present part forms the opening portion of the second volume and is devoted to a part of the silicates, namely, those of the olivine, willemite, eulytite, garnet, phacelite and topaz-andalusite groups. Some idea of the fullness with which the species are treated will be gathered from the fact that 13 pages are given to olivine, 26 pages to topaz, etc. With topaz, for example, we have first the crystallographic characters, the axial ratio, list of forms, calculated angles, etc.; then the physical characters and optical constants very fully given with references to the original papers; then a review of the history of the species with respect to its names, composition, etc.; then follows a general statement of method of occurrence, with a very minute description of all the important localities, with an account of the crystals from each and references to the authors who have treated of them. The figures of crystals are scattered through this part of the text as referred to. An account of the artificial mineral and a list of analyses, including also alteration products closes a most complete and interesting chapter. Very little attempt is made at condensation, and if this takes something from the compactness of the whole it certainly adds to the clearness of presentation.

The portion of the work at hand is too small to allow of a satisfactory judgment in regard to the general classification to be adopted, but it seems to follow the usually accepted methods. Danburite is placed with topaz and andalusite, etc., though the chemical composition does not show the same analogy that exists in the form; nephelite, however, is not included with the related silicates $KAlSiO_4$, $LiAlSiO_4$ $NaAlSiO_4$ since it deviates from the unisilicate formula. We are surprised to find this last group named after Scacchi's "phacelite," while the fact that Scacchi's

mineral was described two years earlier under the name of *Kaliophilite*, is overlooked. The appearance of the succeeding parts of this great work will be looked for with interest, and it cannot fail to receive the cordial reception which it deserves.

6. *Mazapilite.*—The new mineral from Mazapil, Mexico, described by KOENIG (see this Journal, xxxvii), proves upon further examination to be a calcium-iron arseniate near arseniosiderite. An analysis gave:

As_2O_5	Sb_2O_5	P_2O_5	Fe_2O_3	CaO	H_2O
43·60	0·25	0·14	30·53	14·82	9·83=99·17.

The mineral occurs in prismatic orthorhombic crystals, which are black in color and only translucent and blood-red on the thinnest edges; the specific gravity is 3·582.—*Proc. Acad. Nat. Sci. Philad.*, 45, 1888–9.

III. BOTANY AND ZOOLOGY.

1. *Ueber Entstehung und Wachsthum der Zellhaut;* EN. ZACHARIAS (Pringsheim's Jahrb., xx, 2, p. 107).—The root-hairs of Chara fœtida were used as materials, and the process of growth by which the cell-wall is formed and grows, was followed out step by step on living cells. The new formation begins with the appearance of minute granules out of which minute rods are produced which become wider and longer and finally unite to constitute a coherent membrane. Between these rods one may see at first some protrusions of protoplasm, but then later withdrawn. But the origin and chemical relations of the granules which are seen at the outset are as yet undetermined. Growth in thickness is demonstrated to take place by the mechanical apposition of new rods, and also by intercalation. Growth in superficies is believed to be explained best by a combination of the two theories of intussception and of apposition. G. L. G.

2. *Volvox* has been investigated afresh by L. KLEIN (Pringsheim's Jahrb., xx, 2, p. 133).—The following are his conclusions: I. *Volvox aureus* and *V. globator* vary extremely with regard to the size and number of the individual cells, the size and number of the colonies produced, and the number of the oospores and bundles of antherozoids. But, on the other hand, the size and shape of the oospores of both are constant. 3. The protoplasts are enveloped by a thick gelatinous membrane which does not exhibit a cellulose reaction. The inner space of the colonies is filled with jelly, not with water. 11. Physiologically, a volvox-colony is to be recognized as a community comparable to a colony of bees so far as a division of labor is concerned. 13. The change in the distribution of sex coincides, as a rule, with the time of year. Thus, in spring *Volvox aureus* has predominately non-sexual colonies, and those with pure diœcism; in summer the antherozoids are only in those colonies which are otherwise vegetative; in late summer and autumn there are also the families which are monœciously protozynous. In general the sexual relations are more complicated than was previously supposed. G. L. G.

3. *Zur Kenntniss der fixen Lichtlage der Laubblätter;* by G. KRABBE (Pringsheim's Jahrb., xx, 2, p. 211).—The experiments were confined principally to the leaves of Phaseolus and lead to the following general conclusion which is somewhat at variance with those recently announced by Vächting. The position of the leaf with respect to light cannot be explained on the basis of a simple combination of heliotropism, epinasty, etc.; it is the result of a *special* heliotropic property of leaves. G. L. G.

4. *Flora*, oder *Allgemeine botanische Zeitung.*—This well-known journal, now in its 72d year, changes its place of publication. Hereafter it is to be edited at Marburg by Prof. K. Goebel. The number for March 1 begins the new volume. It contains (1) an interesting paper, by the editor, on the young forms of plants, (2) a criticism by Prof. Pfeffer on the researches by Loew and Bokorny, (3) notes on *Hypoxis decumbens* by Ludwig, (4) the genus Crenacantha (certain algæ placed by Hausirg near Draparnaldia), (5) (6) papers by J. Müller on Sandwich Island and Argentine Lichenes, (7) Widmer, notes on the red primroses of the Alps, (8) Loesener, some new plants from Brazil, and, finally, two reviews.

The second number, May 15, has (1) Schenck, on the aerial roots of *Avicennia tomentosa* and *Laguncularia racemosa*, (2) on the liquefaction of gelatine by moulds, Hansen, (3) the sandflora of Mainz, by Jännicke, (4) Weisse, on the mechanical theory of leaf arrangement in axillary buds, (5) short notes giving information relative to a botanical journey of Bornmüller in Asia Minor, (6) Lichenologic notes by Müller, and, lastly, four reviews, one of them being an appreciative notice of the Botanical Gazette.

The foregoing list serves to indicate the wide range covered by the journal under its new editor. It should receive hearty encouragement. G. L. G.

5. *The utilization by plants of free atmospheric nitrogen.*—At the close of a very interesting article in the Berichte der Deutschen Botan. Gesellsch. for June 25th, Prof. Frank, after having reviewed certain points in dispute between Helbriegel and himself, says: "All plants use as nitrogenous food at least in their young state, and up to a certain degree of development, compounds of nitrogen, especially nitrates, which they take from the soil; under a favorable condition of development they can also assimilate free nitrogen from the air. The gain from the latter depends in amount on the energy and duration of this assimilation; for instance, in the Leguminosæ it is especially marked. * * * * Just as we attribute the carbon of humus and of peaty soil to the carbonic acid of the air, we must attribute the nitrogen of arable land to the nitrogen of the air, both of these having been acquired through the intervention of the vegetable world." G. L. G.

6. *Monographiæ Phanerogarum Prodromi nunc continuatio, nunc revisio Editoribus et pro parte auctoribus* ALPHONSO et CASIMIR DE CANDOLLE. *Vol. Sextum. Andropogoneæ, auctore*

EDUARDO HACKEL. (Paris, pp. 716, 2 plates.)—About 60 pages of this volume are given up to an instructive review in German, of the principal feature of this tribe of grasses, and the characters which the author has used in his revision. The second plate exhibits graphically the supposed relations of the genera, regarded from the point of view of development. In the main line of descent stand Miscanthus, Erianthus, Pollinia, and farther on, in the same straight line Andropogon, while there branches off from Pollinia an oblique line with Ischnæum, Rottboellia, and Ophiurus. Elionurus and Cleistachne are given off on either side of Andropogon, or, rather, its sub-genus, while Sorghum comes in the Cleistachne offshoot. G. L. G.

7. *Angewandte Pflanzenanatomie;* by DR. A. TSCHIRCH, (vol. I, pp. 548.) Wien, 1889.—This work gives the principal applications of Vegetable Histology to the Arts, especially to Pharmacy, Agriculture, and Technical Industries. The first volume confines itself to a general sketch of general anatomy considered from almost every point of view. The book is copiously illustrated with woodcuts, many of them original, and all of remarkable clearness of outline. The paper is much heavier than we usually find in German books, and, in this case, it contributes greatly to typographical excellence. It forms the best practical work of reference for the laboratory that we have yet seen, covering all the ground thoroughly in a careful survey. A second volume, which is to deal with the more important drugs, fibres and the like, is in preparation. This work can be unreservedly recommended to all who have to examine the tissues of plants for any purpose whatever in the arts. G. L. G.

8. *Report on the Mollusca from dredgings of the Steamer "Blake," under the Supervision of* ALEXANDER AGASSIZ; by W. H. DALL. Part II, the Gastropoda and Scaphopoda. 492 pp. 8vo, with 31 plates.—Bulletin Mus. Comp. Zool., vol. xviii. Part I was published as No. 6 of vol. xii.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Soaping Geysers.*—Mr. ARNOLD HAGUE, in a paper read before the American Institute of Mining Engineers, in February last, gives the results of some trials of the effect of soap in the waters of geysers in hastening geyser action. The discovery with regard to it was made by a Chinese laundryman at the Upper Geyser Basin, who found that the soap produced an eruption in every way similar to that of the ordinary working of a geyser. Mr. Hague's experiments proved that geyser-action could be forced in a number of ways, but most conveniently by the use of soap. Lewis's concentrated lye in half-pound packages was used in the trials. The more powerful geysers in general did not respond to the influence. Old Faithful, the interval between whose eruptions is about 65 minutes, or generally between 57 and 72, afforded no positive results. With the Bee Hive, whose eruptions

vary greatly in interval, from a few hours to weeks and months, there was rarely success, but sometimes twice in a day. The Giantess, which is only 400 feet from the Bee Hive, has a large basin without a cone or mound, and varies from 12 to 20 days in its very copious and long-continued discharges, never was found to yield to artificial methods of hastening action. With some other geysers there was frequent success.

Mr. Hague concludes that the acceleration of action takes place when the waters are in a super-heated condition. He remarks that the experiments of Dr. William Hallock have shown that this is a common condition in some geysers. "If in one of these super-heated basins a handful of sinter pebbles be thrown, or if the surface of the water be agitated by the rapid motion of a stick or cane, or even by lashing with a rope, a liberation of steam takes place, which is liable to be followed by a long boiling of the water, and the boiling may lead to geyser-action. The laundryman's spring is only a hot spring, and never acts as a geyser without treatment with soap,—with one exception, in which, stirring it vigorously with a pine bow for nearly 10 minutes, produced a play to a height of 20 feet.

When soap is used the viscosity produced appears to be the principal cause that hastens geyser-action. The waters are too dilute and not of a nature to be chemically changed by the lye.

Mr. Hague observes, in closing his paper that the desire of tourists to soap a geyser during their trip through the Park grows annually with the increase of travel, so much so that there is a steady demand for the toilet-soap of the hotels. If visitors could have their way, the beautiful blue springs and basins of the geysers would be in the suds constantly throughout the season. Throwing anything into the hot springs is now prohibited by the government authorities. It is certainly detrimental to the preservation of the geysers, and the practice cannot be too strongly condemned by all interested in the National Reservation.

2. *Proceedings of the Colorado Society*, vol. iii, Part I, 1888. 186 pp. 8vo.—This number of the Proceedings of the Colorado Society contains among its articles, Mineralogical papers by W. F. Hillebrand, H. S. Washington, F. F. Chisholm and S. G. Eakins; papers on the Denver Tertiary formation by W. Cross and G. H. Eldridge; on the Tertiary Dinosauria in Denver beds, by G. L. Cannon, Jr.; on the Tertiary of the Huerfano River Tertiary, by R. C. Hills; on the Quaternary of the Denver basin, by G. L. Cannon, Jr.

3. *The Chemistry of Photography;* by Raphael Meldola, F.R.S. 382 pp. London and New York, 1889, (Macmillan & Co. —Nature Series).—The perfection of modern methods in photography has made the processes largely mechanical and reduced to a minimum the necessity of a knowledge of its scientific principles. It still remains true, however, that the worker who will attain the best success must have a thorough knowledge of the chemistry of the various processes, such, for example, as can be

gained from this attractive little volume. The subject is presented here in the form of nine lectures, originally delivered at the Finsbury Technical College in 1888, and this form makes it the more readable and gives it less the character of a text-book.

4. *Ostwald's Klassiker der exakten Wissenschaften.* Nos. 1, 2, 3. Leipzig, 1889 (Wilhelm Engelmann).—The publication of this valuable series of scientific classics is a real service to the scientific student. The numbers thus far issued are:

No. 1. Ueber die Erhaltung der Kraft von Dr. H. Helmholtz.

No. 2. Allgemeine Lehrsätze in Beziehung auf die im verkehrten Verhältnisse des Quadrats der Entfernung wirkenden Anziehungs- und Abstossungs-Kräfte von Carl Friedrich Gauss.

No. 3. Die Grundlagen der Atomtheorie; Abhandlungen von J. Dalton und W. H. Wollaston (1803, 1808).

On the Classification of the Early Cambrian and Pre-Cambrian formations, by R. D. Irving, pp. 367 to 454 of the Seventh Annual Report of the Director of the U. S. Geol. Survey, Washington, 1888.—This very valuable paper is the last work of the able geologist. It makes manifest the greatness of the loss which the Government Survey experienced in his decease.

The Faults in the Triassic formation near Meriden, Conn., by Wm. Morris Davis. 24 pp. 8vo, with 5 plates. An important paper in the discussion of the origin of the Triassic trap ejections of the Connecticut valley.

The English Sparrow, *Passer domesticus*, in North America, especially in its relations to Agriculture. Prepared under the direction of Dr. C. Hart Merriam, Ornithologist, by Walter B. Barrows, Assistant Ornithologist, U. S. Dept. Agric., Washington, D. C., 1889.

Catalogue of Fossil Reptilia and Amphibia in the British Museum. Part II, containing the orders Ichthyopterygia and Sauropterygia; by R. Lyddekker. London, 1889.

Etudes sur les couches Jurassiques et Crétacées de la Russie; by Prof. A. Pavlow, with 3 plates of figures of fossils Relates especially to the beds at the junction of the Jurassic and Cretaceous.

The Mineral Wealth of British Columbia, with an annotated list of localities of minerals of value; by G. M. Dawson, D.S., F.G.S. Geol. and Nat. Hist. Survey of Canada, Part R, Ann. Rep. for 1887. Montreal, 1888. (Dawson Brothers.)

Discovery of fossil-bearing Cretaceous strata in Anne Arundel and Prince George Counties, Maryland, by Prof. Wm. B. Clarke, Johns Hopkins University Circular, No. 69, 1889.

A Manual of Chemistry for the use of Medical Students, by Brandreth Symonds, A.M., M.D., Assist. Physician to Roosevelt Hospital. 154 pp. 12mo. Philadelphia, 1889. (P. Blakiston, Son & Co.)

Cercle Chromatique de M. Charles Henry, presentant tous les complements et toutes les harmonies de Couleurs, Paris, 1888. (C. Verdin). Rapporteur Esthétique de M. Charles Henry, permettant l'étude et la rectification esthétique de toute forme. Paris, 1888. (G. Séguin).

OBITUARY.

Elias Loomis.—Professor Elias Loomis, the eminent meteorologist, connected since 1860 with the Faculty of Yale College, died in New Haven on the 16th of August, at the age of seventy-eight. A notice of his life and scientific work is deferred to another number.

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III. **American Journal of Philology.**—B. L. GILDERSLEEVE, Editor. Quarterly. 8vo. Volume IX in progress. $3 per volume.

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